

Design a MicroGrid Component for SmartGrid Architecture

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Abstract - This work reports the development of a system composed of electronic shield and client-server software installed inside the device to acquire real-time data. The goal is to propose an applicable smart micro-system to optimize the current grid. The micro-grids allow an optimal way to manage energy flow by direct injection in the electric network. In contrast from conventional systems, micro-grids can communicate between them to carry energy to places that have higher demand in accurate moments. This system does not require energy storage, so costs are lower than conventional systems like fuel cells, add solar panels or else, even though micro-grids are independent systems they are not isolated, the main reason, we need to control the smart-grid by a server application, which modify the behavior of each micro-grid for social benefits. The impact of this work is the improvement of the electrical network without having greater control than an intelligent network (SMART-GRID); specially in inefficient networks because they waste energy trying to transmit, generate and distribute energy in long distances and others factors that can affect the performance, i.e. Ecuador only the 65% of the energy is used in optimal way, the other 35% is wasted. If we can implement a smart-grid this leads to move to a 20% increase in energy in a specified network but this process demands to standardize methods and remain in place to support all future technologies and the best option is the Smart Grids and Micro-Grids.

Keywords: Mini-Grid, Micro-Grid, Smart-Grid, Internet Of Things, Smart-Architecture.

1. Introduction

Some countries are developing different concepts about smart-grid topology. In Ecuador, the Government is working to change the energetic matrix to reduce the use of oil, so our main goal will be to implement Smart-Grid systems into this project because they optimize the electrical network. The most important goal will be to avoid the dependence on oil to generate electricity. In Ecuador about the 35% of the electricity is leaking because the long distance that has to go through from generation to consumption. If we can create a method to reduce the distances or improve the network quality will be called Smart-Grid, but different from others proposals, we use the internet and micro-grids architecture to solve the long distance problems and inject electricity directly to the network from the Aeolian generators or solar panels installed in houses' roofs for example.

In this document we will focus primarily on the development of a device (prototype) that will manage the electricity distribution into the grid.

Many countries are working for different standards about Smart Grids topology and policy, i.e.

EEUU: through National Institute of Standards and Technology (NIST), and the Institute and Department of Energy (DOE), are managing the Smart Grids on The United States of America; NIST, has identify 75 kinds to transform the actual networks.

EU: European Committee for standardization, CEN, European Committee for Electro-technical standardization (CENELEC) and European Telecommunications Standards Institute (ETSI) have at least identify 110 kinds of the most important ways to open a source architecture to measure electricity.

Japan: This country has other way of thinking; all efforts are centred on less carbon dioxide emission.

China: This government bet for low cost houses, renewable energy, in this moment \$586 dollar billions are being invested for these applications.

Ecuador: The target of this country is to create a Smart-Grid; by this time, The Government is creating a strategy for that. The principal step that the Government has done is that they create an alliance with Huawei's company to try to introduce this technology.

Ecuador has initiated a transformation process model, from being an exporter of raw material to become a society that will export products based on knowledge and biodiversity. By changing the productive matrix, according to the government, Ecuador will provide products with high added value. Ecuador is betting to change its production model in a long term, where the change of imports and exports, along with innovation, science, technology and knowledge will allow giving a massive step in to the future [1].

Even though in Ecuador Smart-Grids systems could be implemented, this kind of technology is available the most of the time for first world countries, which have a bigger economic power than countries that have a poor economy. In the same way, business that owns this kind of technology will create technological dependency due to they are owners of the systems that also impose policies that are beneficial for their industry but not for the industrial development of the country.

We create an environment to supply all this troubles through designing devices which main goal is to optimize the energy consumption. We are working on detecting the main standards proposed for the main countries that are at the forefront in this field to make part of this research and topology; therefore we propose an open-source and open-hardware architecture based on the lowest cost design and implementation.

In the past creating this architecture was unthinkable, in fact the Web Application was not design for this proposals, conventional servers like “Apache” is unable to manage this kind of topology and they are not create to connect and communicate by physical devices. Internet was not created to carry information in small devices but this is changing; internet has achieved by “internet of things” a new philosophy: connect all the stuff at the network, for that reason NodeJS server born. NodeJS can solve this problem because they can create real time applications without refreshing every page.

When the NodeJS appears in the middle of 2011, it change the web world because it could have more than 64000 connections at the same time; this is more than “Tomcat Server” where the number of users is approximately 4000 connections. In another hand, NodeJS uses the benefits of a V8 engine of Google Chrome plus its asynchronous power. This means, NodeJS can change all variables together or independently in real time without the need of recharge the browser. This makes the NodeJS the most efficient tool to be used to attain the goals of tis work.

2. Research questions

The following research questions will drive this work:

- Are NodeJS a suitable tool to integrate systems based on client-server?
- Can we perform a device that manages micro-grid with low cost building?
- Can this topology be easily implemented in Ecuador?

3. Objectives

The following objectives have been established:

- I. To Design a web platform to control, view and instrument a Smart grid trough low cost microsystems.
- II. To design a control to optimize energy resources trough low cost hardware.
- III. Start a process for technological disintegration and reverse engineering to develop industrial innovation that will contribute to change the productive matrix.

3.1. Specific Objectives

- I. To Design, program and implement a platform for Smart-grid control with low cost components for internet access by using meter basic variables.
- II. To create a network tool that can scrutinize metrological processes trough physical variables.
- III. To spread the national and international investigation congresses to generate a paper that may be published in index magazines.

4. Methodology

Smart Grid needs to solve two issues: hardware and software, which can scope to many different places: Smart Home, Smart Car, Smart Industry and more, in this case, we engage in a microgrid architecture posture that we consider is the heart of a smart-grid.

What is a Microgrid?

A microgrid is a set of devices connected themselves through the network with the target of obtaining more efficient electric resources; but this interconnectedness means that when part of the grid needs to be repaired, everyone is affected. This is where a microgrid can help. A microgrid generally operates while connected to the grid, and the most important thing is that it can break off and operate on its own by using local energy generation in times of crisis like storms or power outages or other reasons. A microgrid can be power by distributed generators, batteries, and/or renewable resources like solar panels. Depending on how it's fuelled and how its requirements are managed, a microgrid might run indefinitely.

Microgrids allow:

- Switching injection /non-injection.
- Redirect the energy flow through the network for a specific place.
- Storage or consumption energy in microgrid.
- Use renewable resources.
- Everybody can convert an electric generator, which each microgrid can to do electricity injection in a network.
- Sense different conditions, i.e. power consumption, eleyg oscillation, temperature, power quality, and so on.

Hardware Microgrid components:

- Each device is Smart.
- Connect directly via Internet through Wi-Fi or UTP wire.
- Logger all controlled data.
- Battery supply.
- Server Hosted.
- Connect with others devices, transducers and sensors.
- Relay outputs.
- Digital Inputs.
- Each device has an OS.

Software Microgrid components embedded:

- Client-Server.
- Cloud storage.
- Autonomous algorithm for control.
- Internet control device.
- Hosted web server.

Platform architecture:

Figure 1 presents the APP (Application web). This platform allows to connect to the device (micro-grid), view the variables, personalize the dashboard and determinate the behavior of the micro-grid shield. When the user sign in to the App (is programmed in NodeJS), he or she can find all the devices that are connected in their net, for example: if one home has three micro-grids (i.e. roof, devices, and smart-car) and all of them are plug in to the micro-grid shield, each one could be control independently but the setup will be configured through the app. The user can view on the dashboard the variables (global or independent) for each device; in another hand we could turn on/off the energy flow.

The control devise must do four basic duties: acquisition, analysis, data reporting and monitoring. This devise has the chance of add more functionality without extra money spending, but it's not all to will doing, the most important, this can be take a decisions on critical moments, connect/disconnect any device in a real time, with intentionally for cause more benefits to electrical network.

From computers use was essential in measuring the analysis of such data in histograms that allows to have control and a feedback of the process, but this was not only the advantage of using virtual instrumentation; now a day we can integrate this technology with different industrial equipment Programming Logic Control (PLCs), inverters, among others, transforming complex manual processes into automated processes, where it is preponderant the use of virtual instrumentation as a principle of decision-making, minimizing the human errors improving quality of peoples live.

Flexibility, low maintenance cost, reusability, customizing each instrument, the fast introduction of new technologies, low cost per channel and function are some of the benefits of the Smart-grid integration. Mainly the greater impact it has on the energy industry was the emergence of the terms "flexible automation" which involves synapses between different elements that are acting on a grid and can have an impact depending on the behavior of different variables.

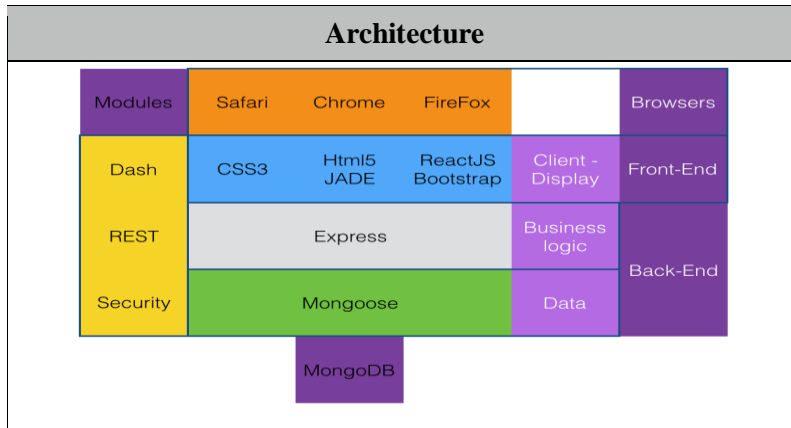


Fig. 1: WEB Architecture.

Figure 2 contains all characteristics of the app; these are the primary components.

Components	
OS	Multiplatform
Application Server	NodeJS IOJS
Languages	JavaScript
FrameWorks	Mongoose Express
DataBase	MongoDB
Dispositives	SmartPhones PC Tablets

Fig. 2: Web Components.

What is NodeJS?

Node.js is a JavaScript runtime built on Chrome's V8 JavaScript engine, which uses an event-driven, non-blocking I/O model that makes it lightweight and efficient. This is package ecosystem Node Packages Manager (NPM), is the largest ecosystem of open source libraries in the world. For that reason, NodeJS are the best tool for develops our APP. As an asynchronous event driven framework, Node.js is designed to build scalable network applications. This is in contrast nowadays more common concurrency model where OS threads are employed. Thread-based networking is relatively inefficient and very difficult to use. Furthermore, users of Node are free from worries of deadlocking the process, there are no locks. Almost no function in Node directly performs I/O, so the process never blocks. Because nothing blocks, less-than-expert programmers are able to develop scalable systems. Node is similar in design to and influenced by systems like Ruby's Event Machine or Python's Twisted. NodeJS takes the event model a bit further; it presents the event loop as a language construct instead of as a library. In other systems there is always a blocking call to start the event-loop [2].

Why NodeJS?

For more reasons NodeJS is the best server for drive the APP, between them:

- Because, it Open-Source, and it can be 64000 concurrent connections.
- JavaScript programing.
- The best tool for web application.

The most relevant characteristics for the NodeJS:

- Web development in a dynamic language (JavaScript) on a VM that is incredibly fast (V8). It is much faster than Ruby, Python, or Perl.
- Ability to handle thousands of concurrent connections with minimal overhead on a single process.
- JavaScript is perfect for event loops with first class function objects and closures.
- A lot of people already know JavaScript, even people who do not claim to be programmer. It is arguably the most popular programming language.
- Using JavaScript on a web server as well as the browser reduces the impedance mismatch between the two programming environments, which can communicate data structures via JSON. Duplicate form validation code can be shared between server and client, etc.
- Multiplatform.
- Programs executing one task in one launch, so-called scripts.
- Executable applications, such as different types of servers. But in such application a developer should apply to some rules in order to provide high capacity. All actions should be smaller in order to keep high level of capacity, and also we should check that the application isn't overloaded by memory consumption.
- Asynchronous and Event Driven.
- Very Fast Being built on Google Chrome's V8 JavaScript Engine; Node.js library is very fast in code execution.
- Single Threaded but Highly Scalable.
- No Buffering.

Where to Use Node.js?

Following are the areas where Node.js is proving itself as a perfect technology partner.

- I/O bound Applications
- Data Streaming Applications
- Data Intensive Real time Applications (DIRT)
- JSON APIs based Applications
- Single Page Applications.

The micro-grid shield allows data acquire signals for process, for example for current, temperature consumed and the lux for the any areas, also it can power on/off any devices and finally and more important it has big capacity for management the switching of electric flows, between consume and produce energy in this way, the micro-grid together conform a mini-grid, that you can see on Figure 3.

The application will have the following peculiarities (Figure 4):

- I. Local and two-way communication with a prototype (hardware) for control and automation.
- II. An interface where the user can create an instrumentation panel for monitoring critical variables (Temperature, humidity, electric current and voltage and more).

The micro-grid shield allows data acquire signals for interconnected among all through internet way, and all information are send to the app, where the user can manage the behavior the each ones. The diagram —‘Figure 4’, represent the components that the shield architecture has.

The Mini-Grid is conform by many micro-grids set's, this behaves like a network, where all information is send to the cloud through Internet for the app, like the picture above —‘Figure 4’. When the Mini-Grid produces more electricity than the electricity that is consumed allows the energy to flow from the Mini-Grid to the electrical network.

Hardware characteristics:

Nowadays, each microgrid can allow

- Connect to PLC.
- Connect to many different devices, i.e. sensors (4-20mA, 0-5 Volts) or digital sensors, engines, electro-valves, frequency variation, thermocouples, and others.
- Multi-voltage, 110/220 VAC, 50/60Hz.
- Connect themselves.

Figure 5, show the schematic architecture and the interaction between API REST on server and APP client side. In a Server side, this part storage all data from the client App and all the information captured for the Mini-Grid Shield, which is connected through the USB cable, Wi-Fi or Ethernet wire.

We were building a testing bench, this component was based on mega system micro-controller embedded which are made a ATmega2560, and BCM2835 with a ARM1176JZF-S central processor; the micro-controller do all things about the

peripherals sensors and actuators and BCM2835 process all data from the micro-controller and server hosted, the data is divide; one for the APP client and the other for the server, there are disposed for: cloud storage, signal process and telemetry process. The communication between micro-controller and BCM2835 is UART Serial with sampling rate 115200 bps.

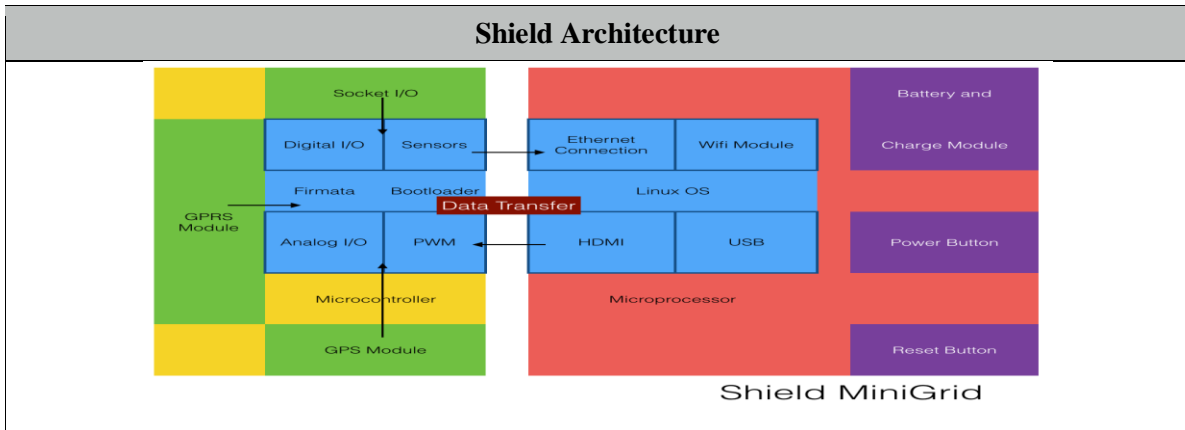


Fig. 3: Shield Architecture Micro or Mini Grid.

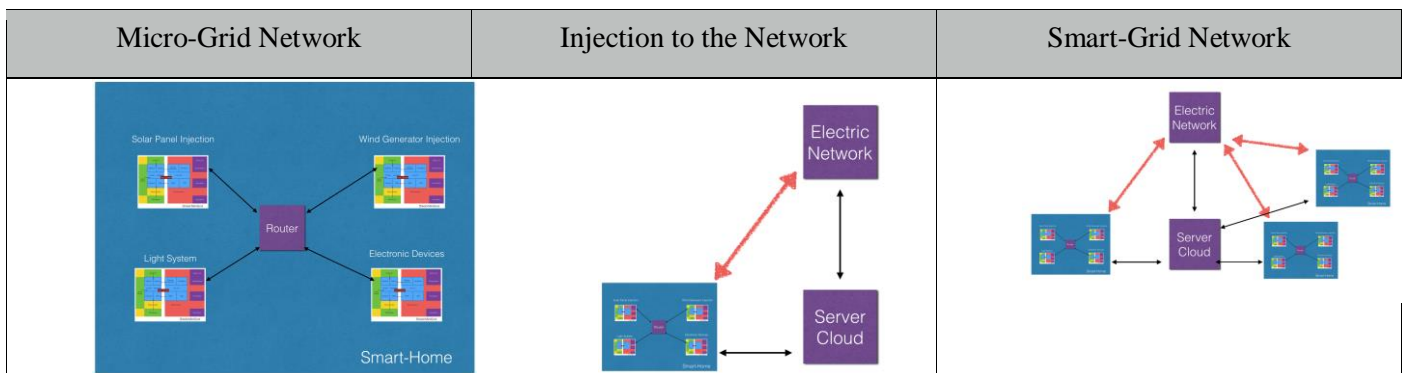
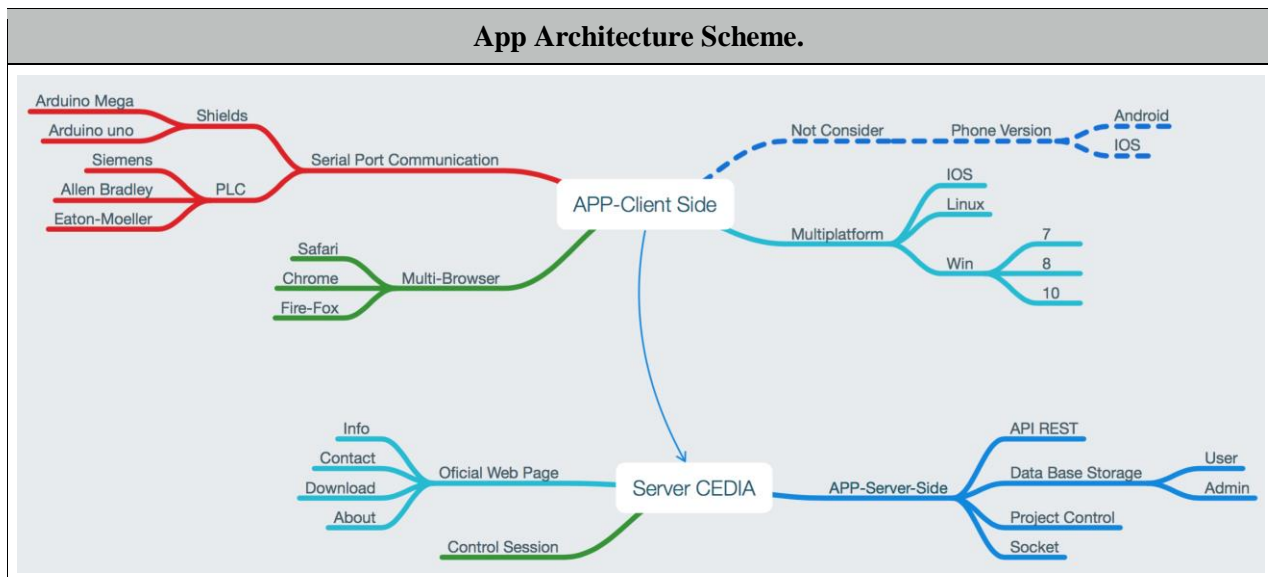


Fig. 4: Architectures Topology.



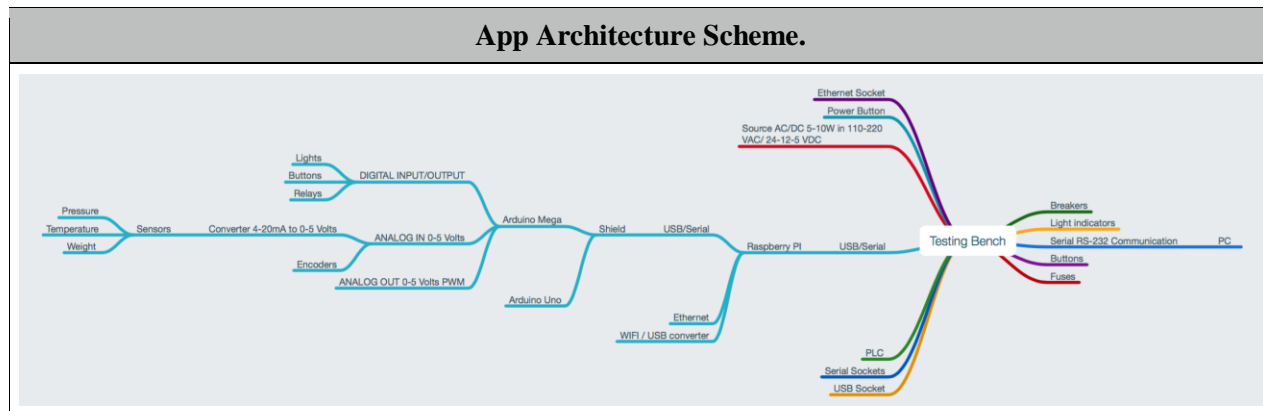


Fig. 5: App Architecture Scheme.

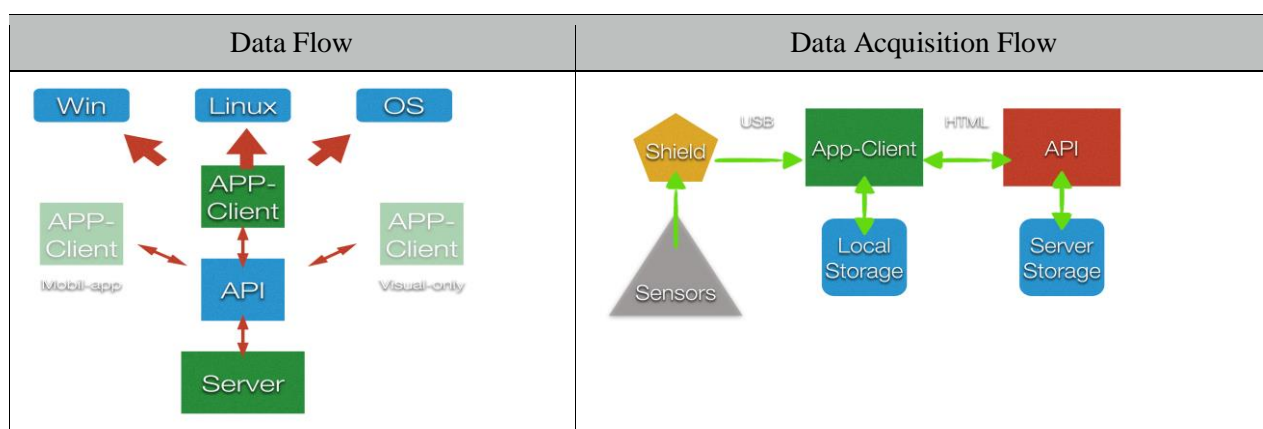


Fig. 6: Logical Topology App Layer.

The user can download the app-client from own repository webpage, and install, after that you need to authenticate, connect the testing beach and plug the sensor that you need being process; or the user need a telemetry monitor, only access through the own web-page and authenticate.

The app let on each user can be create many dashes for visualize everybody variables, these actions over the app should create a program that can be burn on the shield directly to setup and modify the behavior of it; this is the main difference with from others systems, because we can obtain the micro-controller program through a web-app, for this logic, we consider the importance to write a research and a paper.

5. Conclusion

- NodeJS is the best tool for propose, because join´s all the characteristics for the develop platform, mainly because this is a new trend and standard in a web-develops.
- Nowadays, the tendency for industrial and domestic apps are the web-applications, which each needs communication through www, small delays, quickly data information, for this reason we consider that architecture above exposed meets all the request.
- Approach the Smart Grid through Mini-Grid to simplify the problem, because a mini-grid can be a multipurpose devise and it could be adapt in a field.

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