# Urban Node (2013) Creating a new urban element to turn Vilanova i la Geltrú into a Smart City

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***Abstract* - The importance of constant communication and real-time availability of information has had an important impact on everyday life, due to the almost constant availability of the Internet. In this context, a new concept is gradually emerging: The Smart City. This is why the Urban Node project was created.**

**This project is performed in collaborative work between four multinational engineering students, university professors and a local company. The main objective is to create a new urban element that meets the needs of the citizens in terms of service. It can replace the street light with a more efficient light solution and has to be modular. It produces more energy than it spends, and should be easy to maintain. This goal is reached by using existing technologies and assembling them in a smart way.**

**This team is working in the electric and electronic design. By researching similar projects, existing electronic solutions and technologies it has created a way to realize the idea of the Urban Node and created a prototype. All the electronic components (microcomputer, microcontroller, sensors, etc.) are in different boxes that plug into a rack, which allows modularity. This modular design enables customization and easy modifications in the future.**

***Index terms* – data acquisition, intelligent structure, smart city, Urban Node**

## I. INTRODUCTION

In order to convert the city of Vilanova i la Geltrú (VNG) into a Smart City, the city government, represented by the city owned company Neàpolis, has given the Universitat Politècnica de Catalunya in Vilanova i la Geltrú (UPC) the following project: Create an "Urban Node – It is an element of the street which does things, communicates with each other and with the world, and also, if necessary, gives light", taken from Neàpolis introduction meeting with EPS and IDPS.

The Urban Node is a part of the approach Neàpolis is taking to enhance the city of VNG, hoping to attract people and business. In a modular design the Urban Node could replace the old street lights and provide not only light, but several useful functions for the citizens as well as collecting information about the city environment and produce electric energy.

This will be possible by using Information and Communication Technology (ICT) to enhance city services and its infrastructure, adding intelligence to the city environment and the municipality.

The Urban Node project is divided into two separate projects: one project focuses on the electronic part and another on the design. The electronic part, which concerns all the inside of the Urban Node is assigned to the EPS, and the design part, which represents the outside of the Urban Node, is assigned to the IDPS. EPS and IDPS are divided into two separate teams, but they work together on collaborative tasks.

## II. OBJECTIVES

The objectives of the Urban Node are given by Neàpolis. The main objective is to produce a solution for a new family of urban equipment. The idea is to build a new urban element that creates access to information, communication and produces more energy than it spends. It is consisting of modular parts depending on the needs of the environment the Urban Node is placed in. One of the modules will be an LED lamp, so it can replace the existing street lights of the city. The Urban Node has to create more energy than it spends, be ecological, easy to recycle, easy to maintain, durable, expandable (allow for future changes), modular, secure for the population and finally this solution needs to be economical. The aim is to attract people and encourage them to use the Urban Node by making the user experience enjoyable and covering people needs. The EPS part of the project has to decide on the electric and electronic design of the entire structure based on the objectives.

## III. DESIGN GUIDELINE

### *A. Survey*

The future Urban Node has to contain different modules useful for all citizens. As a first step, it is intended to be implemented in VNG. Therefore it is important to gather feedback from these citizens and inquire about their needs. The answers from the participants can permit us to see which type of module in our Urban Node is attractive to them and better understand our users' needs.

VNGs population is about 67.000, therefore 67 locals were participating in the survey.[i]

| Adge | Pourcentage |
|---|---|
| *0 to 14 Years old* | 16% |
| *15 to 64 Years Old* | 68% |
| *65 to 84 Years Old* | 14% |
| *More than 85 Years Old* | 2% |

Age division in groups of the people participating in the survey

Most of the participants have lived in VNG for more than 5 years, and the majority works. The majority of the people goes to the beach just during the summer and not at all during the rest of the year, although it is assumed that people still use the promenade around the beach for a walk or similar activity all the year around. An early idea of location was the sea facade, but based on this new information the area has been enlarged to include La Rambla, the main walking street of VNG, because 53% of people pass time or walk around this place.

One important question to get answers from, especially for the EPS, was which module or function people preferred the most. The people participating were asked to pick three functions from the list below which appealed most to them and which they would like to have in their street environment.

- Free Wi-Fi (27%)
- Mobile phone chargers (12%)
- Interactive displays (11%)
- Parking facilities (11%)
- Information about the streets of the time and weather (11)
- Rent a bike/skate (8%)
- Apparatus for physical exercise (6%)
- Controls vehicle speed near schools, hospitals (5%)
- Video Surveillance (4%)

From the results it is possible to see the most popular functions and this is a good start to understand user behaviour and their needs.

*B. Concept of Modularity*

In order to allow flexibility and alternatives to one standard solution, most components will be modular. This means the components in the Urban Node can be customized, avoiding unnecessary costs and material. The modularity is realized by dividing the electronic parts into core modules and additional modules, such as sensors.

The core modules will be in every single Urban Node, giving it computing power, ability to connect to optional modules and the possibility of transferring electrical energy from a renewable energy source into the electrical grid as well as powering the Urban Node itself. This gives the Urban Node the possibility of having a large number of different sensors and modules. Depending on the streets environment and customer wishes and needs, every single Urban Node can be custom made with modules chosen from a catalogue.

A track in the standard box will ensure that each box will only be able to be plugged into the rack in one specific way, so anybody can change modules without special technical education. To suit most sensors, the box will be ventilated. This ensures that for example temperature and humidity sensors will give accurate information.

All these boxes will plug into a motherboard, on which there are connectors for USB, the sensor bus architecture and additional power supply. This ensures the connection of most modules with the Acquisition Unit or even directly with the Brain Unit.

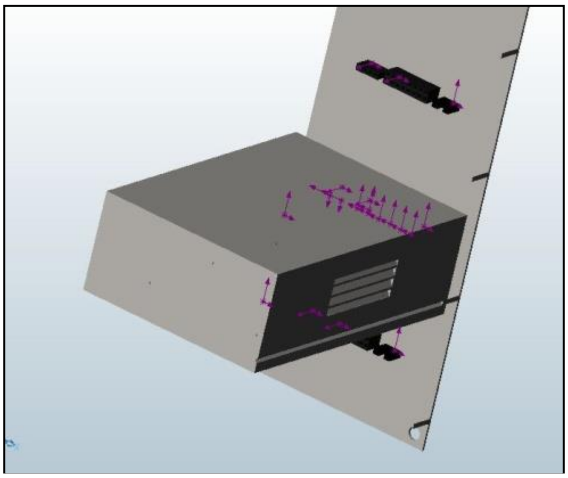


**Figure 1 – Motherboard with standard box**

IV. ELECTRONIC PROPOSAL

*A. Core modules*

*A.1 Acquisition Unit*

Since the Urban Node is supposed to realize a number of functions connected with monitoring the environment around it, a unit responsible for gathering and processing data is required. Monitoring the environment is vital for energy saving features of the Urban Node and providing information required by a Smart City. Therefore, the Acquisition Unit should be robust and reliable. The proposed solution for this purpose is using Arduino and a number of Arduino-compatible sensors to collect the data. More information about Arduino and why it was chosen is presented shortly in chapter B.1 *Arduino (Acquisition Unit)*.

*A.2. Brain Unit*

The Brain Unit is the central intelligence unit of the Urban Node. All information will be fed into the Brain Unit either directly, or through the Acquisition Unit. It should be powerful enough to do normal computer operations and it has to be able to communicate with the other units. Its task is to process data from sensors, cameras, etc. and use it or send it to a control center. In other words, this module will be responsible for controlling other units and managing the Urban Node. The device proposed for being used as the Brain Unit is Raspberry Pi. Information on the Raspberry Pi is presented in chapter B.2 *Raspberry Pi (Brain Unit)*.

*A.3. Power Unit*

One of the Urban Node's main functionalities is producing sustainable energy. This can be realized in various ways, but in this project the sources of energy will be limited to photovoltaic panel[ii] and wind turbine[iii]. This is due to the fact that these devices combine relatively small dimensions with good power characteristics. They are described in detail under the Sustainable Energy chapter. Secondary ways of producing energy, which might be incorporated in this project in the future, include stationary exercise machines and a piece of pathway generating energy while being stepped on. All of these technologies have already been successfully implemented in other projects. They are so called off the shelf solutions, and will be described in further sections of this article. Generally, the Power Unit is responsible for managing energy produced and required by the Urban Node.

*B. Components*

*B.1. Arduino (Acquisition Unit)*

The heart of the Urban Node’s Acquisition Unit will be the Arduino Uno.

Arduino is an open-source electronic platform, made to be easy-to-use in both hardware and software. Physically, it is a credit card sized microcontroller-based board with a number of input and output ports, which makes it easily expandable. It can pick up information from the environment by using sensors connected to it; it can also control its surroundings, for example lamp or a motor.

Arduino Uno Rev3 is the chosen version. It is based on the ATmega328 microcontroller, has 32kB of flash memory, 16 MHz clock, 14 digital I/O pins and 6 analog input pins. It can be powered via its USB port (for example from a PC) or power port from an external power source.[iv]

Due to insufficient number of input pins, it is necessary to use a multiplexer and demultiplexer (chip selector) to allow for the possibility of connecting a larger number of sensors.

*B.2. Raspberry Pi (Brain Unit)*

The Raspberry Pi is a very small single-board computer, similar to Arduino. It is about the size of a credit card. It is powerful enough to do normal computer operations and it can communicate with other units. The Raspberry Pi will handle the information acquired by the Arduino. The Raspberry Pi will then process the data and send it to a control center.

Its heart is the Broadcom BCM2835 chip, which is composed of ARM1176JZFS 700 MHz processor, VideoCore 4 GPU and 512 MB RAM.[v]

*B.3. Demultiplexer*

Demultiplexer is a logic electronic device having input line, x address lines, $2^x$ output lines and some control signals. It is used when a certain signal is supposed to be sent to one of many devices connected to its output lines. For this project we have chosen to use 74HC154 digital demultiplexer as 4-to-16 line decoder.[vi] This means that only one of its 16 outputs is active, while the other 15 are inactive. This demultiplexer comes in PDIP24 package. This means it can easily be used on a prototype board and later mounted on standard socket designed for its size.

*B.4. Analog multiplexer*

A Multiplexer is the opposite of a demultiplexer – it has x address lines, $2^x$ input lines and 1 output line. It passes the signal from one of its input lines to the output line. In our case we have decided to use an analog multiplexer – this means that any voltage level on its input is passed to its output as opposed to digital multiplexer, where output can have only two voltage levels corresponding to logical truth or false. For this project we have selected 74HC4067 analog multiplexer.[vii] Similarly to 74HC154 it comes in PDIP24 package of exactly the same dimensions.

*B.5. MOSFET transistor*

MOSFET (metal-oxide semiconductor field-effect transistor) is a voltage controlled transistor. When proper voltage $V_{GS}$ is applied across two of its terminals (gate and source), the transistor starts conducting current between another pair of terminals (source and drain). This voltage is called threshold voltage ($V_{GSth}$). When the voltage $V_{GS}$ is lower than the threshold voltage, the transistor stops conducting.

In this project IRF9530N power transistor was used.[viii] It can conduct up to 14A current. Therefore it is often used in high power applications.

*C. Architecture*

By putting electronic parts into boxes and standardizing the size of the boxes (meaning the boxes would all have the same dimensions), the architecture achieves modularity. For example, creating a standardized box for all the elements, allows for a rack system inside the Urban Node where you can easily add or remove a box. Standardizing the boxes also gives an economic benefit; the manufacturer only needs to construct the same dimensioned box.

The current architecture suggested consists of three standard boxes of the same dimensions having different content:

- Raspberry Pi
- Arduino
- Sensor

## V. ARCHITECTURE

The three core modules, described above, form the backbone of Urban Node electronic architecture. Additionally a number of sensors, multiplexer and demultiplexer (forming a chip selector) are used.

Below in fig. 2 there is presented a scheme of the architecture. In the scheme, power connections are marked in red, data connections in violet, control signals in green and bus connections between Acquisition Unit and chip selector in grey. All of these connections will be realized on the motherboard, since standard boxes will be able to plug into the motherboard.

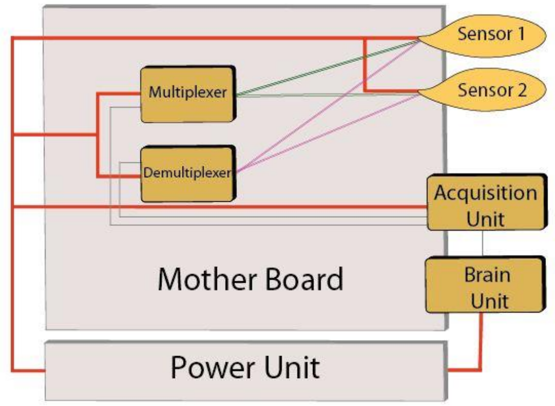



**Figure 2 – Architecture**

In order to save energy, sensors are turned off by the multiplexer when not used. Moreover, the data is passed to the Arduino via the demultiplexer, which allows for using only one analog input pin.

Arduino and Raspberry Pi communicate through a USB cable and use serial communication. More detailed explanation is given in section VII. Programming and in the report.

## VI. PCB DESIGN

A set of circuits responsible for data acquisition and simple light control was designed to realize the project objectives regarding data acquisition and modularity. In order to assemble the designed circuits, first of all a breadboard was used for testing purposes. Later, custom printed circuit boards (PCBs) were manufactured in the university. The software used for circuit design, simulation and PCB design was Altium Designer Summer 09.[ix] In this article, the exemplary design procedure for only one board is presented.

*A. Light sensor*

This was the first circuit designed and manufactured. It uses a resistor and a photoresistor[x] forming a voltage divider. Thanks to this circuit we can evaluate light intensity, since it is proportional to output voltage $V_{out}$.

In order to make this simple circuit work with the chip selector, motherboard and Arduino, the following circuit presented in fig.3 below was designed:

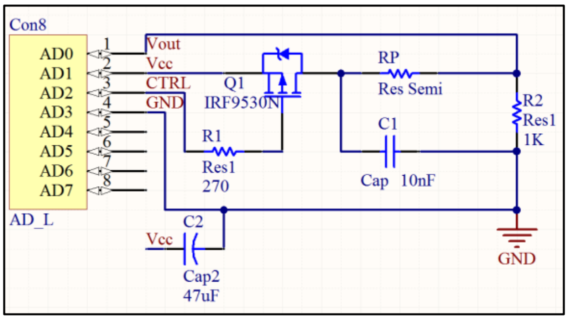
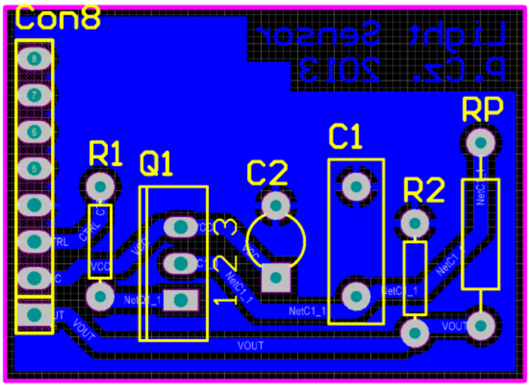



**Figure 3 – Light sensor board**

The simulation results presented in section 7.3.1.1 Light Sensor of the report confirm proper operation of the circuit. In order to test the circuit in reality before manufacturing the PCB, it was tested on the breadboard. During the test, changes of Vout voltage were observed while changing light intensity on the photoresistor. Since observed values corresponded to anticipated ones, PCB was designed. The test is described in details in the report under the chapter Proof of concept.

In the figure below a PCB designed is presented. The board is relatively small, since its dimensions are less than 26x36,1mm. All the connections are realized on the bottom layer and there is a ground power plane covering most of the board in order to minimize noise in the circuit. The track width is set to 1mm, minimum clearance between tracks to 0,5mm and hole size to 0,8mm or 1mm, depending on devices' connector size. These parameters are a result of university PCB manufacturing facility limitations. Moreover, size of pads was increased in order to make soldering easier.

Other PCBs were manufactured in the same manner.




## VII. PROGRAMMING

The Arduino needs code to make all its components function as desired and to send sensor information to the Raspberry Pi. Code was made to control the temperature sensor, light sensor (and control two LEDs based on the sensor reading), multiplexer and demultiplexer. Arduino and Raspberry Pi communicate through a USB cable and use serial communication, which sends sequentially data one bit at a time. The Raspberry Pi receives the data sent by the Arduino, it can view the data and override the control of the Arduino, which was proven successful in laboratory testing.

## VIII. CONCLUSION

In conclusion, the work made for this project has produced solutions to fulfill the objectives set out in the start. This work can be viewed as providing the necessary foundation and giving solutions that are easily scalable, to be continued and produced on a larger scale. It lays the important groundwork to be able to finish the complete product, and decides the further scope for what needs to be done. It presents the solutions on how to realize the idea of the Urban Node, and to finally produce the finished product.

The electronic architecture has been changed two times during this project, when finally the current and superior solution was produced. Raspberry Pi and Arduino are a strong proven combination of microcomputer and microcontroller. Their great popularity ensures further development and support.

By adding renewable energy sources to the Urban Node, photovoltaic cells and Vertical Axis Wind Turbines, it is capable of producing energy. Theoretically it produces more than it spends, to prove this theory it is necessary to construct a extensive prototype and perform testing. Connecting the Urban Nodes with the electric grid ensures power to the node while there is no renewable energy source available (neither wind nor sun), furthermore it allows for selling the excessive produced energy to the grid, when renewable energy is available. Nevertheless the key to the majority of savings the Urban Node will perform, lies in the information acquired by the sensors. For example through smart street lighting and smart plant watering (by monitoring the PH level in the ground), therefore investing in the Urban node will return money to the city budget.

Modularity is both electrically and physically well achieved. This makes the Urban Node future proof, gives it a strong flexible ability to respond to customer needs and preferences as well as adjusting to special environmental circumstances. Because of the modularity expenses and materials are not spent carelessly in a standard solution, rather expenses are no more than what the need calls for.

## ACKNOWLEGMENTS

We would like to express our gratitude for cooperation, support and interest of our supervisors, Pau Martí, an Associate Professor at Universitat Politècnica de Catalunya and Josep Farré, CTO at Neàpolis Company. Their knowledge and expertise made an invaluable input to our project. Moreover, their guidance in the early stages of the project was vital to its later development.

We would like to thank for providing the equipment and practical help with design and assembly of the circuits to technical department of EPSEVG, especially Oscar de Sousa for his assistance in later stages of the project.

Special thanks go to the IDPS team and their supervisors. If it hadn't been for them and their work, this project would not be as complete as it is now.

Finally, we would like to thank all the EPSEVG students who voluntarily contributed to our project.

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