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RESEARCH ARTICLE OPEN ACCESS

WIRELESS SENSOR NETWORK FOR ENVIRONMENT MONITORING IN SMART CITIES

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ABSTRACT

This paper presents a wireless sensor network for environment monitoring in smart cities. The prototype described here was applied in the context of the project Cidades Digitais, a Brazilian program to distribute optical fibersto the cities, at Porto Nacional, Tocantins state, Brazil. In terms of architecture, the system was designed with an ESP 32 DevKit V1; DHT 11 sensor for temperature and humidity; MQ-135 sensor for smoke and toxic gas measurement; infrared fire sensor and the ultraviolet sensor Guva S12SD. The communication with the server implements the RESTful pattern and uses Docker containers to provide scalability, which includes a service to warn registered users about issues, APIs to receive and retrieve the data and a database to store it. The system also counts with a Power BI dashboard to visualize and filter the data collected by the sensor network. Also, it is discussed some performance and efficiency topics surrounding the prototype used.

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INTRODUÇÃO

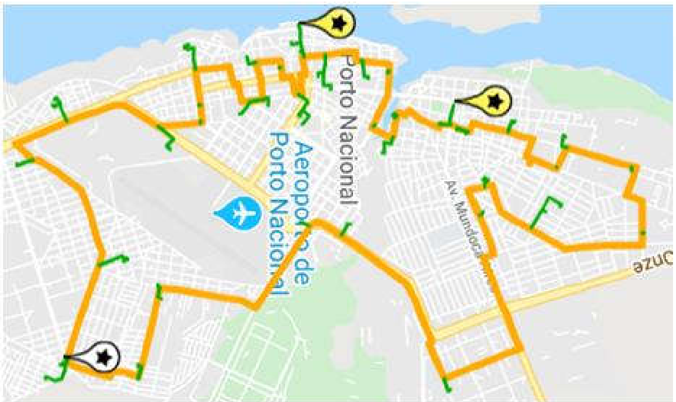
In the next years, many smart devices will be connected and able to communicate with several services, causing huge social and cultural impacts (Alkhabas et al. 2017). Following this trend, the Brazilian Communications Ministry has the Cidades Digitais program (Digital Cities, in free translation), which has as purpose bring modernization to public management, improve society's development and contribute with the communication between public administration and citizens (Ministério da Ciência e Tecnologia, n.d.). In parallel to that, the concern about the environment is getting intensified due to the increasingly expressive manifestations of climate change, as can be seen at Bastiaansen et al. (2020) and Shah et al. (2020).Still inside this scope, air pollution is one of the problems that ravages Brazilian cities, where, according to the Brazilian Environment Ministry, such a situation can be deadly and results in higher spending on the public health system (Ministério do MeioAmbiente, n.d.). The authors Wolkofet al. (2018) and Schulz (2019) report the negative effects of low humidity and high temperature, among who are coughing, headaches, and convulsions. In this way, therefore, this work presents a prototype that uses the CidadesDigitais project as a foundation and can help to attenuate the effects of climate change. The system shown is a wireless sensor network that can provide real-time measures. Thereby, this network gives data that can help to base public policies for mitigation of pollution, adverse environmental conditions and its consequences. In terms of architecture, as will be better explained, this system implements the RESTful pattern with Docker containers, and, for human interaction, there is a dashboard made in Power BI.

The Cidades Digitais Project: The implementation and maintenance of CidadesDigitais Project, by Brazilian Federal Government through Communications Ministry, was instituted by Ordinance nº 376, from August 19th, 2011, aiming to 1) build communication network across Brazilian counties; 2) promote the production and supply of digital contents and services; and 3) facilitate the appropriation of communication and information technologies by local public management and by the population, allowing the integration between the public sector and the citizens (DiárioOficial da União 2011, 2012). The cities that receive the resources to implement the structure provided by the project are select through notice. In 2012, the Brazilian Communications Ministry opened the first contest to choose the pilot-project, where 80 cities were contemplated. In 2013, the CidadesDigitais project was included in the Federal Government's Programa de Aceleração de Crescimento (Acceleration Growth Program, in free translation), an opportunity that benefited, in that year, 262 cities with population up to 50 thousand residents (Ministério da Ciência e Tecnologia, n.d.).

Case Study: Porto Nacional, Tocantins, Brazil: The Porto Nacional city, Tocantins state, adhered to the project on December 15th, 2017, with an investment of 2,142,918.78 BRL from Communications

Ministry (Prefeitura de Porto Nacional, 2012). According to Ministério do Planejamento (n.d.), Porto Nacional is one out of four Tocantins' cities that adhered to the project. In general lines, the project contemplates the coverage of Porto Nacional with an optical fiber network and Public Access Points, henceforth PAPs, on its squares. Currently, the fibers are installed according to Source: Provided by The Porto Nacional's City Hall.

Figure, having three PAPs.



Source: Provided by The Porto Nacional's City Hall.

Figure 1. Porto Nacional's Optical Fiber Network

As can be seen in Source: **Provided by The Porto Nacional's City Hall.**

Figure , the orange route is called ring and it corresponds to the main network. It is through this ring that there is redundancy in the circuit. In green are the drops, which are ramifications that connect the buildings in the network (the points are not shown to avoid polluting the image). Lastly, the three city's PAPs are marked with a star and are distributed as shown in Table.

Table 1. List of Porto Nacional's PAPs

Identification	Location (Square's Names)
PAP 01	Praça da Saúde
PAP 02	Praça Dr. Euvaldo
PAP 03	Praça da Avenida Beira Rio

Source: Provided by The Porto Nacional's City Hall.

In this work, the connection between the sensor network and the internet is through the PAPs.

Internet of Things and Wireless Sensor Network: In line with Singh et al. (2015),the concept of the Internet of Things (IoT) consists of the possibility to connect everyday objects to the internet to improve comfort and productivity. In this context, as exposed by Xing (2020), it is possible to divide an IoT system into for layers: application; support, communication, and monitoring. Still, according to the same author, the application layer is where occurs the interaction with the human world, where it can be, therefore, a messaging application, for instance. On a lower level, there is the support layer, involving the application hosting systems. The servers are located at the support layer too. The next layer is the communication one, being composed by the network that connects the devices. Finally, the monitoring layer is where the system collects environment data. Aligned with Yavari et al. (2019)and Xing (2020), the monitoring layer can be composed either by a single sensor or by a group of them. Netto (2016) highlights the possibility to use a wireless network composed of sensors to monitor small geographic areas. These networks are called Wireless Sensors Networks (WSN). In turn with Netto (2016)andAlkyildiz et al. (2020), the use of WSNs allows precise monitoring in geographic regions where the proportions are small compared to the satellites' resolution used for the same objectives. Still, in line withNetto (2016), the WSN must be designed to consume as little power as possible. It is important to approach the network hops concept too. Said that, the network hops are related to the path that the information travels until reaches the server. In line withNetto (2016), the communication is single hop if each sensor can send its information directly to the server. In case of the information pass through other devices, the link is called multihop.

METHODOLOGY

Figure 1 shows the used material to build the prototype. The Esp32 is the microcontroller, while the DHT 11 is a temperature and humidity sensor, Guva S12SD is used to measure UV Radiation, MQ135 is a smoke and toxic gas sensor, and, lastly, the Infrared (IR) sensor is used to detect fire. It is also important to say that the DHT 11 requires one pull-up resistor and the MQ135 needs more two in its voltage divider circuit.

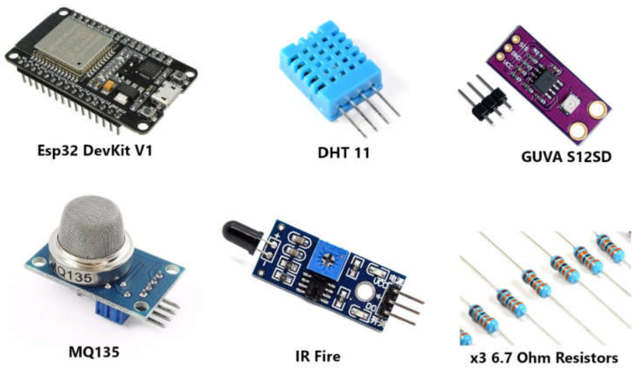


Figure 1. Used Material

Talking about the server, it has installed the operating system GNU/Linux Debian 10. As an isolation layer, the Docker Engine is used to containerize the services. Regarding the programming technologies, the database was made with MySQL 8.0.9. The server was programmed int C# 8.0 with .NET Core 3.1 and ASP.NET Core 3.1. Lastly, the ESP 32 firmware was written in C++ aided by the Arduino IDE. Concerning the user interaction, the dashboard made in Power BI exhibits the data plotted in friendly graphics, where the user can apply temporal and geographic filters. This work calls the measuring circuits as cells, and its operation is simple: it checks with there is any scheduled monitoring. If there is one, each sensor will be read 20 times, then, the means of each sensor will be sent to the server to be processed and recorded. Finally, as a security layer, each cell must log in to send data to the server. Moreover, as previously explained, each PAP has WiFi access points, where the cells can communicate with the server through the internet. Each cell is composed of one Esp 32 Devkit V1 module and the sensors shown in Figure 1. The Figure 2, on the other hand, illustrates the steps of the communication, showing that the microcontroller acts like a concentrator that, after calculating each sensor's mean, sends the data to the server, configuring a single-hop connection. Finally,

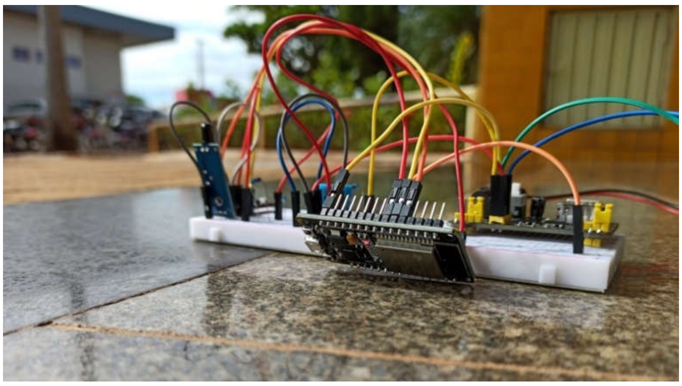


Figure 3 shows the prototype created.

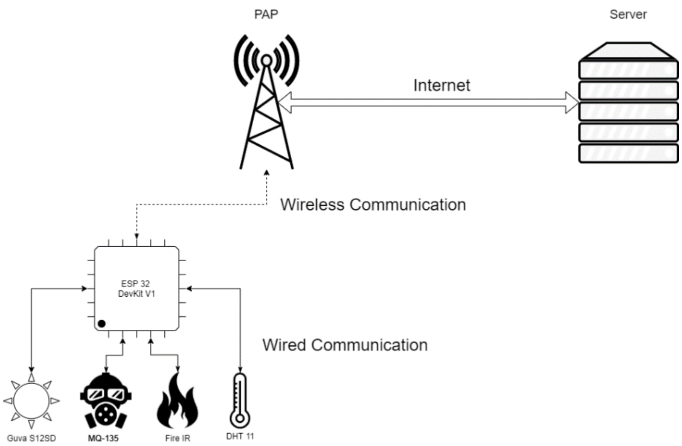


Figure 2. WSN's Architecture

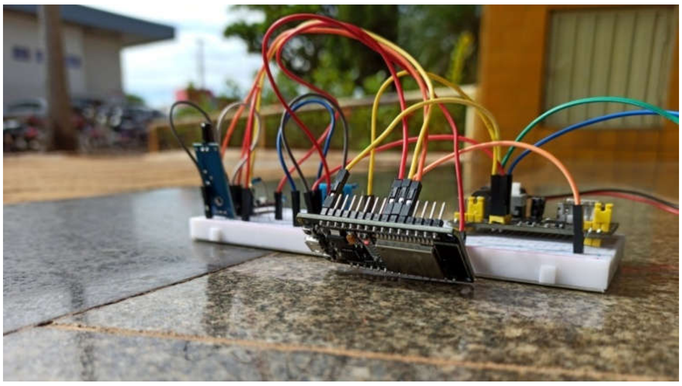


Figure 3. Cell Prototype

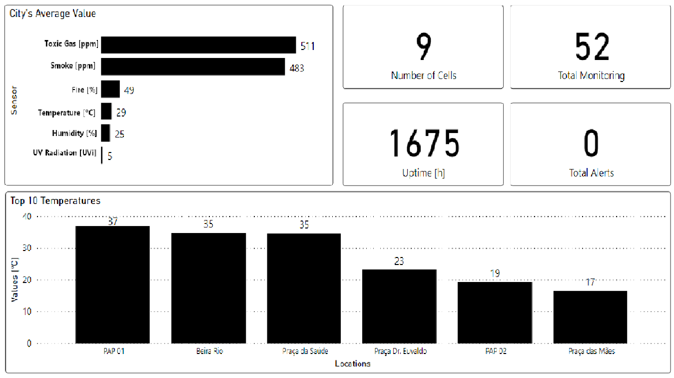


Figure 4. Dashboard's Overview Panel

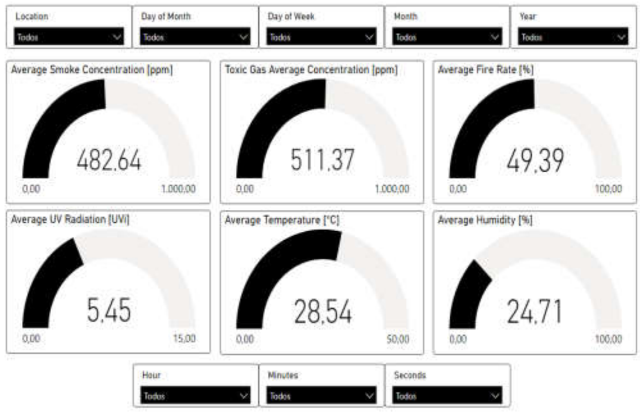


Figure 5. Dashboard's Details Panel

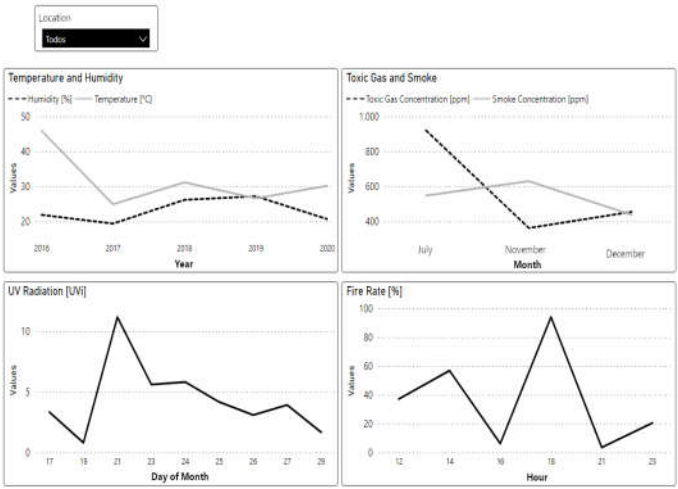


Figure 6. Dashboard's Time Series Panel

RESULTS AND DISCUSSIONS

First, it is important to argue that the summarized data below contains both tests and real information, therefore, the graphics presented here cannot be used as a trusted representation of the city's reality. The reason the leave test values in the dashboard is to generate enough data volume to show all dashboard's functionalities. Figure 4shows the dashboard's first panel, entitled Overview. Some graphics are self-explanatory, therefore, here will be explained only the less intuitive ones:

- **Uptime:** Measured in hours, represents how long the system is collecting measurements. Its value is obtained only subtracting the oldest date from the newest one.
- **Top 10 Temperatures:** This graphics exhibits the higher average temperatures, up to 10 cells, classified by cell's location and in descending order. In Figure 4there are only 6 because only 6 cells were indexed.

Next, Figure 5 shows the panel Details, which allows filtering the measurements by the shown options in both superior and inferior parts. With the filtered data, each speedometer shows the average value of each sensor. Figure 6shows the panel Time Series with average values across time. Here, it is possible to filter by cell's location, and all sensors are shown in four graphics. There is also the drill-down option, that is, it is possible to "zoom in" the time instants. To better understand the drill-down, observe the graphics. The superior left shows the years. By clicking each year, the values are categorized by months with the measures of that year, as can be seen in the superior right graphic. The same principle allows filtering by days (inferior left graphics) and by hours (inferior right graphic). About the tests, the cells behaved as expected, managing to send the correct measurement to the server.In case of a connection intentionally interrupted, the cell managed to reconnect. Said that, it is necessary to comment on some points about the WSN.

Efficiency and Scalability: In terms of data consumption, the REST pattern brings efficiency due to its communication constraints: information is sent in plain text and it is transmitted only the necessary data, avoiding waste. The power consumption is a point to be commented too since the MQ sensorneeds 5V while the others use 3.3V. This difference brings the necessity to use additional components (the voltage divider), which increases the consumption. Therefore, in future versions of this prototype, it is important to search for alternative sensors that work with the same voltage supply level. Another topic to be explained is the fact of ESP 32 DevKit V1 be a development kit and, therefore, it has some components that are not necessary for the production environment. Only as an example, the serial - USB converter is not needed after the microcontroller is programmed. The ideal, in this scenario, is to embed only the module responsible for wireless communication and use a separate programming circuit when necessary. Regarding the scalability, which is how easily a system can grow, it is important to divide the analysis. From the software point of view, the RESTful architecture allows the separation of functions in services, facilitating the construction of distributed systems. In other words, the containers model turns easier the WSN growth. Concerning the hardware, however, it is necessary to reiterate what was said previously: some unnecessary components make the system more expansive, which is a bottleneck when it comes to growing in scale.

Resiliency, Reliability and Security: A system resilience informs how much it is fault tolerant. Regarding the software, the services architecture ensures that a defective service does not harm the remaining ones. When it comes to the network, single-hop communication also prevents a defective cell to damage the others. From the hardware's point of view, however, some additional care is needed: build a case to protect the circuit from the weather and aggregate electric protection circuits to the cells. About the reliability topic, it is worth saying that the server does not validate the data, therefore, the reliability is up to the cell. With this in mind, the cell performs 20 measurements and sendsto the server the mean of these values for each sensor. This algorithm softens the discrepancies caused by noise or disturbs. However, the WSN itself is not capable of verifying if a given sensor is defective or not. The last topic of this subsection is security, which is the software's responsibility in this work. As initial initiatives, the APIs count with a login system, where the credentials are stored at the microcontroller's memory. The cell, therefore, must be physically protected against the population. Moreover, the server is behind a firewall, allowing only the cells to send data through the internet. Lastly, the system has a valid certificate, which ensures that the data sent is encrypted.

User Interaction: Naturally, it is not expected the user to interact with the system's hardware, therefore, this topic is the software's responsibility. In this context, the RESTful pattern is also helpful because of the possibility of building distributed systems. In other words, the services to interact with the user, send messages or even the dashboard are apart from the API, therefore, the user can have many options without the need of the developers to change the API.

CONCLUSIONS

Considering what was previously said, it is possible to conclude that the system here presented is promising. It is important to remember that it is still a prototype and the caveats approached in the previous section will be considered when occurs the implementation in the production environment. In respect with the objective, it stands out that it was also accomplished: the real-time environment monitoring can be used to base public policies to prevent and to combat environmental problems; the system's dashboard gives the administrators graphical information about the cells and the whole infrastructure to build this WSN relies upon the Cidades Digitais project, which delivers, among other things, internet connections in city's several points.

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REFERENCES

Alkhabbas F, Spalazzese R, Davidsson P (2017) Architecting Emergent Configurations In The Internet Of Things. IEEE International Conference on Software Architecture.

Alkyildiz I F, Su W, Sankarasubramaniam Y, Cayirci E(2002)Wireless Sensor Networks: ASurvey. ScienceDirect.

Bastiaansen, Robbin, Doelman, Arjen, Eppinga, Rietkerk (2020) TheEffect of Climate Change On The Resilience Of Ecosystems With Adaptive Spatial Pattern Formation. EcologyLetters.

Diário Oficial da União (2011) Portaria nº 376 de 19 de agosto de 2011. Imprensa Nacional. https://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?jornal=1&pagina=76&data=22/08/2011&_ga=2.33655649.1343006927.1608160949-1410572987.1603282012.

Diário Oficial da União (2012) Portaria nº 186 de 28 de março de 2012. Imprensa Nacional. http://pesquisa.in.gov.br/imprensa/jsp/visualiza/index.jsp?data=29/03/2012&jornal=1&pagina=117&totalArquivos=168&_ga=2.228099933.1343006927.1608160949-1410572987.1603282012.

Ministério da Ciência e Tecnologia (n.d.) Cidades Digitais - Lista de Cidades Atendidas. http://antigo.mctic.gov.br/mctic/opencms/indicadores/detalhe/Cidades-Digitais-Lista-de-Cidades-Atendidas-2.html.

Ministério do Meio Ambiente (n.d.)Qualidade do Ar. https://www.mma.gov.br/cidades-sustentaveis/qualidade-do-ar.

Ministério do Planejamento (n.d.) Cidades Digitais. http://pac.gov.br/infraestrutura-social-e-urbana/cidades-digitais.

Netto G T (2016) Redes de Sensores sem Fio: Revisão. http://netto.ufpel.edu.br/phd/lib/exe/fetch.php?media=survey.pd.

Prefeitura de Porto Nacional (2017) Porto Nacional Se Torna Cidade Digitalcomo Maior Investimento Feito Pelo Ministério.http://www.portonacional.to.gov.br/index.php/noticias/sec-de-comunicacao/993-porto-nacional-se-torna-cidade-digital-com-o-maior-investimento-feito-pelo-ministerio.

Schulz D (2009) Efeitos da Temperatura no Corpo Humano. Universidade Federal do Rio Grande do Sul. https://www.if.ufrgs.br/dschulz/web/efeitos_temp.htm.

Shah U K, Dulal, Bansha H, Awojobi (2020) Food Security and Livelihood Vulnerability to Climate Change in Trinidad and Tobago. Food Security in Small IslandStates

Singh S, Singh N (2015) Internet of Things (IoT): Security Challenges, Business Opportunities & Reference Architecture for E-Commerce. IEEE.

Wolkoff P (2018) Indoor Air Humidity, Air Quality, and Health – An Overview. International Journal of Hygiene and Environmental Health.

Xing L (2020) Reliability in Internet of Things: Current Status and Future Perspectives. IEEE Xplore.

Yavari A, Georgakopoulos D, Stoddart P, Shafiei M (2019) Internet of Things-Based Hydrocarbon Sensing for Real-Time Environmental Monitoring. IEEE 5th WorldForum on Internet of Things (WF-IoT).

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