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Preservation of Cultural Heritage Sites using IoT

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Abstract—**Religious/historical buildings ought to be preserved for as long as possible. The ancient structures themselves and the rich collections they store represent irreplaceable wealth for future generations. They also provide the space for the customs and traditions to sustain. In addition, cultural heritage sites can stimulate economic growth but need to be maintained as well. This paper proposes an effective and affordable solution for the monitoring of preservation conditions of the Church belonging to Eastern Orthodox cultural heritage. The solution is based on utilization of modern Information and Communication Technologies (ICT) and services with general structure and main design principles using the three-layer IoT architecture. This research is an ongoing work only involving the first step towards realization of preservation monitoring system.**

Keywords-component; IoT; cultural heritage; preservation

I. INTRODUCTION

Heritage and Culture are fundamental parts of any country. They represent the values and traditions of the people belonging to that particular country. In addition, religious/historical inheritance as part of immovable cultural heritage plays a key role in the identity of many people by providing a belief system as well as sense of belonging.

According to the United Nations Educational, Scientific and Cultural Organization (UNESCO) [1] cultural heritage can be classified as tangible and intangible cultural heritage. Furthermore, tangible cultural heritage can be classified as:

- movable cultural heritage (paintings, sculptures, coins, manuscripts),
- immovable cultural heritage (monuments, archaeological sites, religious/historical buildings), and
- underwater cultural heritage (shipwrecks, underwater ruins and cities).

In 2006, the Commission to Preserve National Monuments of Bosnia and Herzegovina (BiH) [2] declared the Old Orthodox Church complex situated in Sarajevo, BiH, as a national monument. The complex consists of the Church of the Holy Archangels Michael and Gabriel, a church yard, a museum building, a fence wall, an entrance gate, a parish house and accompanying movable cultural heritage (Fig. 1).

The museum building contains a collection of 140 icons, four iconostasis fragments, a collection of 114 items made of metal, a collection of 13 books, a collection of six old documents, and a collection of 37 liturgical fabrics as well as embroidery. The Museum of the Old Orthodox Church of the Holy Archangels Michael and Gabriel in Sarajevo was estimated to contain the fifth collection of icons in the world [3]-[4]. In addition, the Church holds a special body relic: hand of St. Thecla, saint of an early Christian Church.

Figure 1. The Church of the Holy Archangels Michael and Gabriel in Sarajevo (Old Orthodox Church)

Cultural heritage sites can contribute to the economic growth but also require policies in place for their preservation. According to UNESCO as more tourists visit cultural heritage sites worldwide some sites are getting neglected in terms of preservation policies [1]. Monitoring of those cultural heritage sites can be first step in organized approach not only to preserve current state of the sites but also to provide future generations with an easy access to values and traditions of their ancestors.

This work proposes an effective and affordable solution for the monitoring of preservation conditions of the Church based on the utilization of modern Information and Communication Technologies (ICT) and services. The proposed solution represents the first step towards the realization.

II. RELATED WORK

In [5], the authors use an open source hardware to develop microclimate monitoring system in the historic/religious building in Cordoba, Spain. They monitor two of the most responsible environmental parameters namely temperature and humidity as it has shown that temperature variations and high humidity cause various damages to immovable and movable

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cultural heritage. The authors use 15 microclimate stations inside and outside of the building. They noted variations of parameters within the building in response to presence of visitors, outside weather conditions and location of the microclimate station. Moreover, the authors suggested using additional sensors measuring other parameters might be beneficial.

A research by [6] investigate influence of the temperature and humidity on Dormition Cathedral in Moscow, Russia in the five-year time frame. In this study temperature and humidity were monitored in the air environment as well as the construction itself to evaluate effect of climate control system on preservation state of wall paintings and iconostasis in the Cathedral. Results obtained in the first couple of years of study allowed for changes in the climate control system and significant improvement of microclimate parameters. This created a platform for better preservation of the monument itself.

The authors in [7] explore, analyze, and categorize preservation of body relics of saints in Orthodox Christian tradition. It was concluded that preservation procedures differ depending whether it is a whole or partial body relic. In both cases authors noted that constant temperature and low humidity are important preservation factors.

In [8], the authors recognize that most frequent parameters causing the increase degradation rate of materials used in movable or immovable cultural heritage are imbalanced values of temperature, relative humidity, UV-radiation, and air pollution. Authors introduced twelve key risk indicators based on previously mentioned parameters, combined it by means of developed algorithm and produced one indoor air quality index. This approach is intended to support custodians of heritage sites through simplified processing and evaluation of monitored data.

A research by [9] gives an overview of the tools and the current state of digitalization of cultural heritage sites in BiH in an attempt of contributing to its preservation. The authors in [10] have developed the remote sensing ZigBee network system for monitoring cultural buildings in order to protect cultural heritage. The proposed architecture is stable, robust, and modular with a projected lifetime of 10 years.

The inclusion of modern ICTs, such as the Internet of Things (IoT), in monitoring the cultural heritage environments has already shown the huge potential. The IoT has been used for monitoring building structural health, cultural preservation and revitalization [11]-[12], as well as for improving the user experience of the cultural environment [13]-[17].

Cultural heritage situated in churches in particular contain the wealth that is invaluable and made up of different materials that are susceptible to environmental conditions and hence must be preserved against natural deterioration and usage. Our proposed approach monitors several factors that can greatly influence degradation of cultural heritage. We consider humidity and temperature as major meteorological variables and several air pollutants. In addition, we consider implementing gas and smoke, vibration, and ultrasonic sensors as well as xylophage detectors.

III. THE PROPOSED SYSTEM ARCHITECTURE

Preservation of the cultural heritage buildings, as well as important relics contained within the buildings, is a costly job. In order to prevent the fatal damages and need for the expensive restoration, this paper proposes a low cost, simple, non-invasive, and efficient IoT-based solution for real-time monitoring of preservation conditions of the Church of the Holy Archangels Michael and Gabriel in Sarajevo (Old Orthodox Church).

The proposed solution consists of three-layer IoT architecture (Fig. 2), and its schematic representation is shown in Fig. 3:

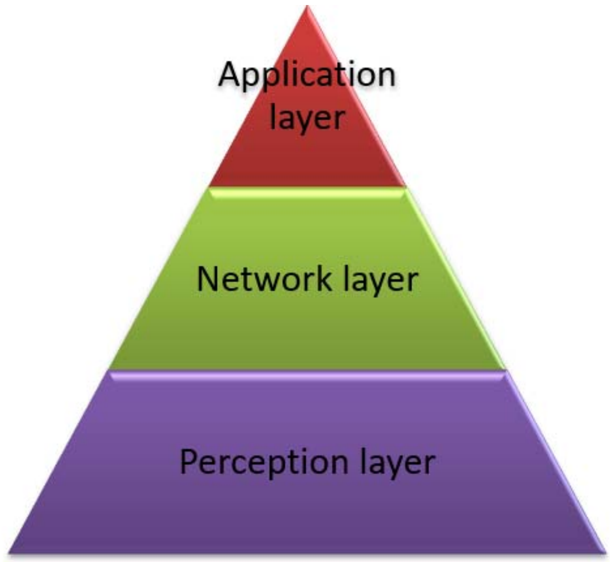

Figure 2. The three-layer IoT architecture

- the perception/sensing layer - is composed of small, cheap and powerful devices that are capable to sense, process and communicate. For measuring the conditions that may influence the Church external and internal structure health, a variety of sensors, deployed in adequate checkpoints, can be used. Heat detectors and temperature sensors can be placed indoor and outdoor. Alongside temperature variations and thermal shocks, humidity and presence of a variety of gasses can also do harm to the relics, what implies the need for the use of gas and humidity sensors. The air pollution sensors can be placed indoor and outdoor to monitor the air quality. As the Church location is near the main city road, the noise and vibrations caused by the traffic are very present in the Church area. Thus, we suggest the implementation of vibration sensors to discover any problems with the building stability. The role of ultrasonic sensors helps in the determination of the damage presence and positioning in the building construction. Furthermore, the Church indoor has a set of wooden components (beams, fence, furniture). In order to prolong their lifetime, the xylophage detectors can be used to detect the wood insects. All these sensors can be attached to the programmable small computer board Raspberry Pi that we propose as a key building element of the solution due to its small size, low costs, customizability, and powerfulness. The Raspberry Pi has built-in support for many input and output peripherals and network communication [18], what makes it adequate part of proposed IoT-based solution. The Raspberry Pi equipped with the sensors becomes a smart device and has an IP address, what makes it unique and identifiable in the network of interconnected devices. After collecting targeted data, they are being transmitted to the upper layers.

- the network/transmission layer – is responsible for transmitting data from the perception/sensing layer to the upper layer and receives data from the upper layer. The PC or even Raspberry Pi can play a role of the gateway of the system. Positioned at the edge of the monitoring network, it interacts with the smart sensor nodes on one side, and with the backbone network on the other side. It can also present a Fog layer that is able to filter out the data, perform simple processing, and forward only the resulting information to the Cloud. In this manner, the traditional problems associated with Cloud solutions, such as bandwidth, and latency issues, are successfully resolved. In order to reduce energy consumption, the utilization of low power communication technologies is desirable. For instance, in the proposed approach the smart devices can communicate with each other using ZigBee, Bluetooth low energy, or WiFi, while smart device and gateway, that can act as a Fog server, can communicate through the WiFi. The data transmission to the Cloud can be realized via Internet connection.

- the application layer – provides data storage, processing or analysis, and smart, high-quality and personalized applications to the end-user (deployed together with the middleware functionalities). The information gathered from the sensors can be stored in both local and remote databases. If there is no Fog level, a variety of data is being stored at the Cloud level. The next step is data filtering and extracting useful information. The goal is to realize the system that will enable the real-time data collection and sharing, locally and remotely monitoring of measured data as well as remote control, based on real-time analysis and visualization. With the help of the knowledge base and machine learning techniques, the right prognosis can be brought leading to the numerous timely and intelligent decisions that will contribute to the prevention of any damages to the movable or immovable cultural heritage. We propose solution using decision tree, support vector machine (SVM) or SVM lite machine learning algorithms as they have capabilities to perform in real-time since their execution time is minimized. In other words, the proposed smart solution, based on the accurate information and right knowledge, automatically brings appropriate decisions.

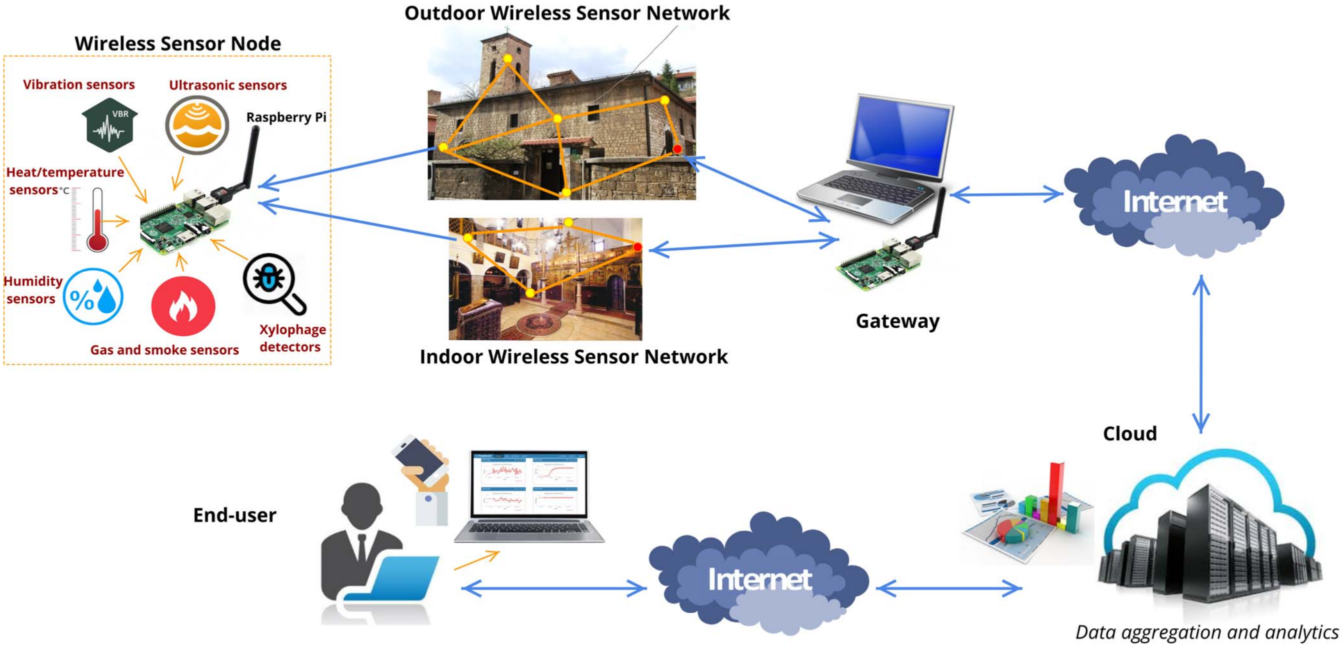

Figure 3. The overall structure of the proposed IoT-based monitoring system

The proposed system is a wireless solution for monitoring the Church of the Holy Archangels Michael and Gabriel in Sarajevo (Old Orthodox Church) in order to protect its cultural heritage. The advantage of this solution is in fact that there is no need for cabling that is costly and invasive, which would not be appropriate in this case. The proposed approach enables 24/7 monitoring of a variety of parameters, generates accurate and specific alerts, hence enabling real-time insights into Church conditions and timely interventions. This solution is modular and can be tailored to the specific use-case scenario by adding the extra components and services. The weak point of the solution is the lifetime as the sensor nodes are battery-driven devices. Prolonging the lifetime of the sensor node and whole IoT system can be realized by consumption reduction. This can be achieved with the help of adequate sleep-scheduling algorithms and implementing harvesting strategies, such as the usage of solar panels.

CONCLUSION

The proposed design represents the first step towards the realization of IoT monitoring environment with its future implementation in the Church of the Holy Archangels Michael and Gabriel complex in Sarajevo. We present the general structure and main design principles using the three-layer IoT architecture. Within the realization of proposed concept we will explore multiple options amongst variety of available sensors, methods in cleaning and processing collected data, procedures for setting alert ceilings, storing of the generated data and approaches of accessing the processed data, in order to select the appropriate candidate for each of the application fields. IoT architecture will be optimized with focus on low price, and energy efficient solution so that such realization and implementation can be provided in other historical/religious buildings.

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