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Preven-T

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PREVEN-T Project Profile

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Partners

INTERNATIONAL HELLENIC UNIVERSITY	International Hellenic University (IHU)	Greece
	Military Academy "General Mihailo Apostolski" (MAGMA)	RNM
	National Park Pelister	RNM

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Abbreviations and acronyms

Deliverable	D
Expected Outcomes	EO
International Hellenic University	IHU
Non-governmental organization	NGO
Land Use Land Cover	LULC

Executive Summary

PREVEN-T is a 18 month duration project funding from the Interreg IPA Cross-border Cooperation Programme: PREVEN-T – CN2 – SO2.4 – SC049.

The overarching objective of the PREVEN-T project is to improve the operational efficiency and the administrative capacity of relevant services in natural disasters management. At the same time project's goal is to enable education, awareness and sensitization of the local population, so that in cooperation with the competent authorities to have a coordinated action to deal with Natural and Technological Disasters and Risks.

The main purpose of this document is to present the main outcomes, advantages and disadvantages of the ASPires platform for automatic fire detection based on a network of land based sensors and data transfer to a cloud environment. Furthermore it intends in demonstrating the areas where the outcomes of the project PREVENT will improve the performance of the platform for early detection of forest fire and mobilisation of fire fighting forces.

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1 Introduction

1.1 Purpose of the document and background

Pelister NP is not considered a typical fire prone area, similar to the ones observed in the Mediterranean region. However, in recent years several publications demonstrate a significant change in fire behaviour with its area of distribution being constantly expanding at higher altitudes and latitudes. This trend has been attributed to two major drivers. The increase of vegetation cover due to agricultural land abandonment and urbanisation and the observed climatic trends of increased summer temperature and decreased summer precipitation leading to increased drought conditions during summer. The purpose of this document is to present the main outcomes, advantages and disadvantages of the ASPires platform for automatic fire detection based on a network of land based sensors and data transfer to a cloud environment. Furthermore it intends in demonstrating the areas where the outcomes of the project PREVENT will improve the performance of the platform for early detection of forest fire and mobilisation of fire fighting forces.

1.2 Intended audience

The intended audience of this document consists of the following target groups:

- PREVEN-T project partners and the Project Officer at the Managing Authority
- Land managers and practitioners in Pelister National Park

1.3 Work Package Objective

The current technical report refers to WP3.1 where its main objective is to identify areas for improvement of existing fire detection platforms and fire-fighting forces mobilisation tools, that have been developed in the frame of previous projects that have been developed and tested in the area. Specifically, building on the experience of the ASPires, DG ECHO project connection of the upgraded system with existing information system which is in the Crisis Management Center. The development of a system for early warning of forest fire risk and its integration to the applied strategy for preventing forest fire and mitigating its effects.

1.4 Structure of the document

In chapter 2, this report describes the results of development and testing of the ASPires platform

In chapter 3, this report summarises the results obtained and provides the expected improvements on its capacity to detect forest fires after integrating the results of the PREVENT project.

2 Research aims and methodology

2.1 Research aims

The BalkanMed area was subject to more than 800 wildfire events during 2014 alone. These fires have spread over 20 Kha of which 25% have been NATURA 2000. Wildfires are deadly events, destroying infrastructures, world heritage sites, wildlife habitats and timber, and also releasing CO^2 in the atmosphere. The effects from the large and reoccurring fires in combination with wrong post-fire management practices are devastating for both natural environment and human communities. Early wildfire detection contributes greatly in the forest protection and reduces considerably the extent of burned forest land.

The almost 90% efficiency of the currently employed fire management in keeping most wildfires at relatively small sizes, even under the most favorable for fire conditions, reveals that this approach, which relies exclusively on fire suppression and traditional methods of fire detection has reached its efficiency limits. This is because it is a small number of fire events which turn into megafires and destroy ecosystems, properties, infrastructures and most importantly have a high cost in human lives, and such events unfortunately are not avoided. Thus, a new approach is needed in wildfire management which will not rely exclusively on fire suppression but it will utilize the technological advancements, the wide availability of remote sensing data and the large amount of research related to risk assessment and fire detection.

ASPires was one of the EU projects aimed to develop cloud-based early forest fire prevention, detection and monitoring systems and concepts. The ASPires project created a novel information and communication cloud platform integrating exiting systems and preparing the area for new virtualized services and models for fire danger forecast and prediction, alerting, fire management, reporting and analysis. It integrates sensor networks, mobile, drone technologies, cloud computing, big data analysis and artificial intelligence while collecting data at existing CMISs. ASPires platform offers opportunity to develop and customise different methodologies and scenarios for initial stage warning, localization and organization of the fire fighting teams and tactics to suppress the disaster. The platform was tested in Pelister National Park via fire simulations that concerned the communication and information infrastructure of the ASPIres platform, and not its validation through actual fire events.

In the frame of the project PREVENT a Fire Danger Index (FDI) will be tested in Pelister National Park that will estimate the fire risk, taking into account the current landscape structure and composition (Firescape), the amount of biomass and flammability of the existing vegetation types and the threat imposed due to anthropogenic activities. One of the main disadvantage of any automatic fire detection techniques is the degree of "noise" which often results in false alarms and the unnecessary mobilisation of forces as well as in the misallocation of resources. The FDI that will be developed will add an additional filter in the detected fires, filtering out alarms that are located in areas with low or zero danger of a wild forest fire, such agricultural or urban areas.

The aim of this report is to describe the architecture and the accuracy of the ASPires platform and to present the ways in which the outcomes of PREVENT will enhance these tactics.

2.2 The ASPires platform

2.2.1. Architecture and overview

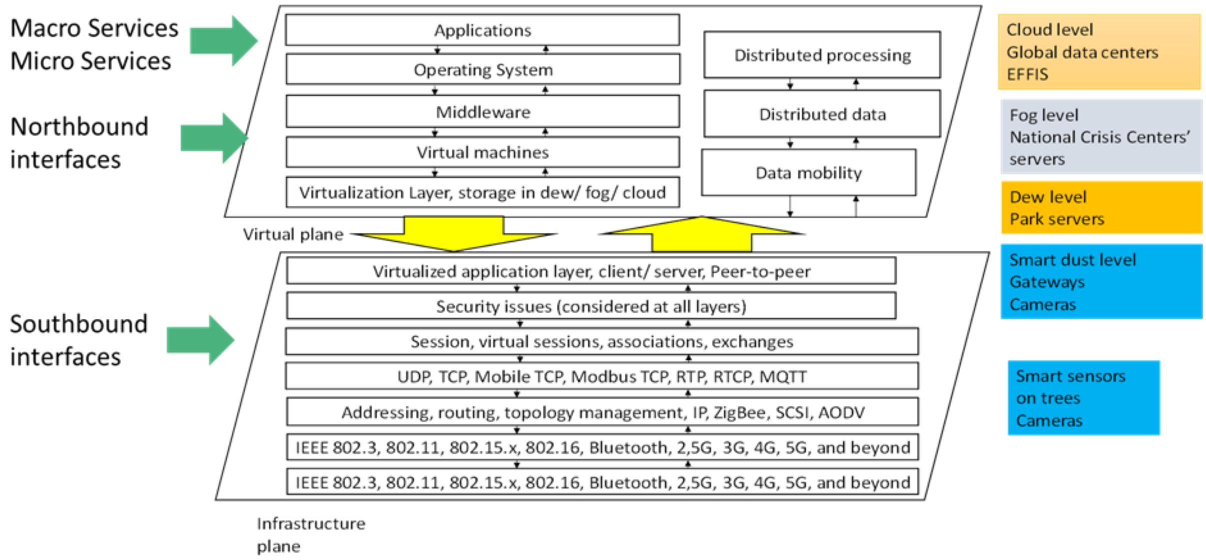

Figure 1. ASPIRES platform architecture reference model

The structure of the ASPIres platform was based on a rather generic reference model (Figure 1) which is less abstract and closer to the real experiments performed under the scope of the ASPIres project. In fact, the network starts with sensors and goes to the cloud. It requires consideration of all kind of components and connections for testing. More specifically, the experiments within the scope of ASPIres project were conducted in the National parks Mavrovo and Pelister, in North Macedonia as well as in other national parks of Balkans and Europe, National park Pirin, Bulgaria, laboratory at University of Applied Sciences, Fulda, Germany, laboratories of other participants (Figure 2). End-users, stakeholders, other bodies, all possible responsible parties in the ASPIres platform are also presented in Figure 2.

The three sensor networks that were simulated used ZigBee, LoRa technologies and cameras. The connections are through ModBus TCP, MQTT, HTTP protocols. The camera surveillance using thermal cameras and HD cameras were performed in Fulda, Germany, North Macedonia and Bulgaria. From communication point of view the only difference is in the bandwidth of the communication channel and the protocol, i.e. HTTP for the video clips and pictures.

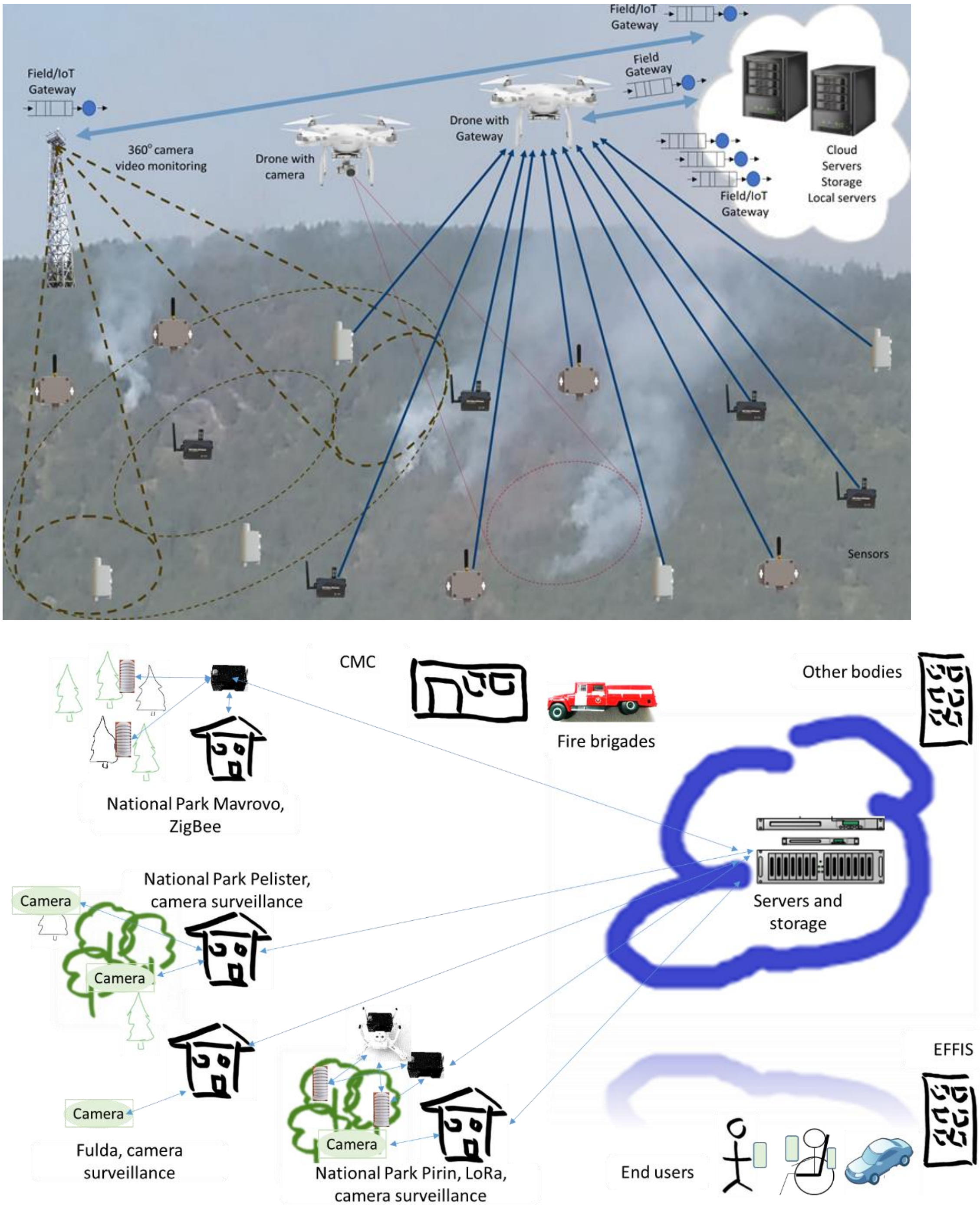

Figure 2. ASPires platform testing places and actors

2.2.2. Simulation results

Although in ASPires there were two types of sensor networks tested and analysed in Pelister NP only the ZigBee was implemented. A simplified representation of the Sensor-to-cloud simulation model is presented in figure 3.

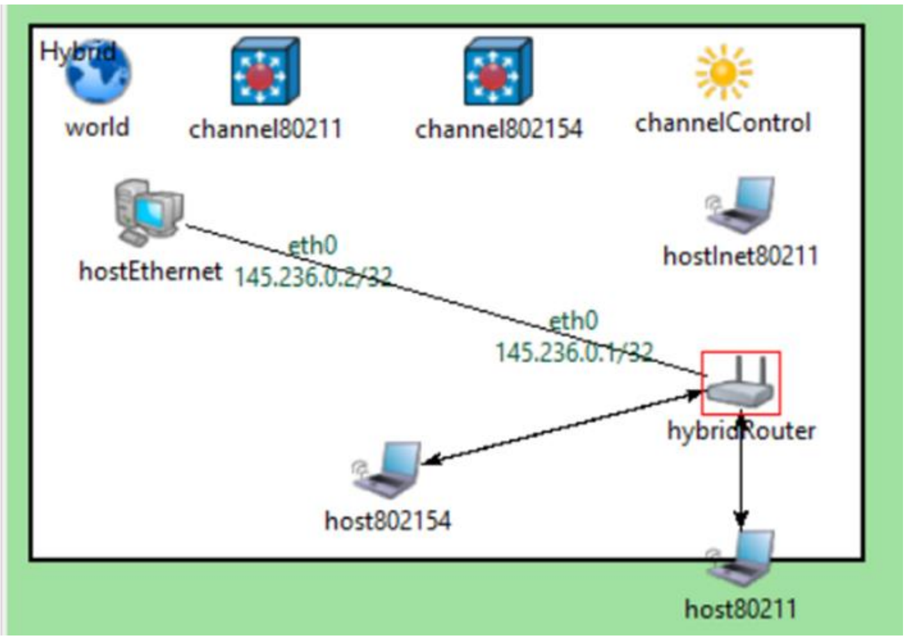

Figure 3. The sensor-to-cloud simulation model.

Various scenarios were tested with different combinations between the number of sensors and distance between sensors and gateways. Round Trip Time (RTT) between 1 ZigBee sensor and the cloud through 1 gateway, when the distance between the sensor and the gateways is 200 meters was found to vary between 0.010592 and 0.050592 s with a mean value of 0,03539531 s. Increased distance between the sensors and the gateway up to 400 m at 10 mW transmission power does not reflect directly the RTT. However, the first losses are observed. The RTT distribution is not significantly different from results at 200 m. The connectivity is lost above 600 m distance between the sensor and the gateway. The only way to increase the distance is to improve the sensitivity, transmission power or signal-to-noise ratio. The maximal round-trip time increased as well as number of duplicates due to the low level of the signal at the distance of 600m.

Simulations from gateway to cloud connectivity were also implemented following the model shown in figure 4. The experiments have been performed with 1, 2, 68, 1000 gateways. The limitations of OMNET++ prevented from obtaining statistically significant results. According to the simulation results the Round Trip Time (RTT) measured end-to-end is between 400 and 700 ms. The total delay is accumulated from the measured separately delays in the routers, in the cloud and at the gateways. Queueing time measured is negligible. Round trip time distribution is changed to the normal distribution when the number of gateways increases. Again, it is important to mention that due to the limits of the OMNET++ the experiments are limited by means of number of samples. The experiment with 10 gateways that could cover a square of 2x2 kilometres show different performance parameters for different gateways.

End-to-end connectivity simulation results are calculated as a sum of the sensor to cloud connectivity and gateway to the cloud and to the application. It did not include the processing time that is considered negligible and could not be modelled with the support of the OMNET++ at this stage. For simplicity the RTTs are not summed here.

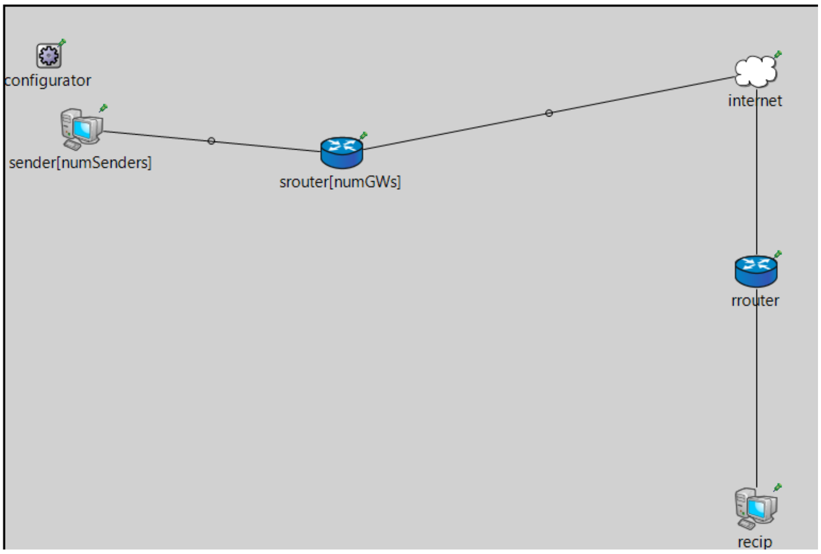

Figure 4. Gateway-to-cloud-to-application connectivity.

According to the simulation results the Round Trip Time (RTT) measured end-to-end is between 400 and 700 ms. The total delay is accumulated from the measured separately delays in the routers, in the cloud and at the gateways.

2.2.3. ASPires Platform Verification and Validation in National Parks Pelister And Mavrovo

Verification and validation are independent procedures that are used together for checking that a product, service, or system meets the requirements and specifications and that it fulfils its intended purpose. Validation is a process of checking that the system meets the customer's actual needs, while verification is concerned with whether the system is well-engineered and error-free.

In order to be able to do an effective validation and verification there is a need of clear understanding of the project goals and system requirements. The goal of this project was to develop an advanced concept of systems for early detection of forest fires by integration of wireless sensor networks and mobile (drone) technologies for data collection, acquisition, and analyses, which will be capable to improve the percentage of detecting of forest fires in areas of importance. These goals were planned to be achieved through:

- Developing and implementing a delay-tolerant network solution.
- Use of energy efficient protocols for hop-by-hop spreading of urgent sensor data (fire alarms).
- Establishing a mechanism for systematic collection of disaster related data.
- Use of cloud technology for processing of huge amount of data and possibility of the use of the cloud computing system and database.
- Cloud services and a way of possible integration to the existing solutions for early fire detections

According to the goals a list of requirements is prepared to ensure a systematic approach towards system verification and validation.

Verification includes regular checking if the system is built on a right course, testing against the specification and insurance that the system is well-engineered and error-free. Verification is needed to help the identification and resolution of any problems, check that the system meets a set of designed goals and requirements and evaluate that the system complies with regulations, specifications, or conditions imposed at the start of a development phase. Verification is performed at the development phase, when it involves performing special tests to model or simulate a portion, or the entirety, of a product, service, or system, then performing a review or analysis of the modelling results. It is also performed at the post-development phase, when it involves regularly repeating tests designed specifically to ensure that the product, service, or system continues to meet the initial design requirements, specifications, and regulations as time progresses. The verification at the development stage was performed by splitting the system into two parts, sensor-to-gateway and gateway-to-cloud and the results were presented above.

The validation process tests the designed algorithm for forest fire detection and determines if the triggered alarms are true or false, i.e. checking the precision of the applied detection process.

During the tests the periods of data collection is confirmed and mapped to the buffer. In this case, the sensor values may show that, for example, temperature increases above the critical values, when in fact this can be a normal occurrence for early morning temperatures.

The proposed approach to early fire detection is based on combination of measured parameters, i.e. many sensors could provide for more reliable fire detection information than just 1 sensor (e.g., heat or gas particles). Following previous research that indicates an increased fire detection accuracy and decreased fire detection time when applying combinations of sensors, the measurements for all parameters are taken into consideration and the obtained values have been synchronized for comparison. During this process, the baseline sensor reading has been the temperature (heat) sensor. All analyses are performed on raw sensor outputs.

The collected data come from one of the controllers installed at the National Park Pelister. The other two controllers were not operational during the first test, due to depleted batteries. Measurements of two separate datasets (events) have been contrasted. The first dataset has been taken on December 4th 2018, when a fire event was induced in vicinity in order to test sensors' reaction to the occurrence of a controlled fire. The second dataset comes from the measurements taken on February 3rd 2019, when no fire has been registered in this area. The purpose was twofold: to determine if fire existence will be detected when there is an actual fire, and to check if the same approach will give rise to false alarms.

For the testing of the systems sensitivity to fire event which was based on the data collected on the 4th of December 2018 the dataset was taken within the time interval from 7.01 AM to 9.53 AM (the test interval) and includes measurement for temperature (T), humidity (H), barometric pressure (P), carbon monoxide (CO) and Carbon dioxide (CO^2). The time intervals between two consecutive measurements were approximately 15 seconds ($\pm$ 2sec). Upon a preliminary analysis of the registered measurements, the critical (threshold) values for the change of each of the parameters had been determined. These values are subject to change and should be evaluated according to the time interval for two consecutive measurements and the environmental conditions. In addition, it has been decided that the measurements for CO^2 are discarded at this point, since the values have manifested unusually intense variations, unexpected for the given circumstances.

In the process of the test analysis, several issues had been noted.

- The time intervals between two consecutive measurements should be approximately equal for the parameter variation approach to be applied. According to the obtained data it would be more appropriate if these intervals are longer, in the range of two to three minutes. This will induce larger critical values for the parameters, which is advisable at the current level of data variations since the registered changes are too small. It will also reduce the inputs that would need to be stored in the database, which currently seems to be too extensive, containing voluminous chunks of registered measurements at a time.
- Battery level is critical for accurate measurement. Low battery levels might result in erroneous measurements, which directly influence the fire detection procedure. However, it is expected that the problem of fast and frequent battery depletion will be considerably decreased during the summer period, when the risk of fire occurrence is at its maximum. Furthermore, to achieve high energy efficiency, active/sleep cycles of the sensor nodes with significantly dominating sleep periods, can be established.
- An additional research is needed in order to determine the normal values and variations for some of the parameters (P, CO, CO^2) in relation to changes of the weather conditions, as well as in relation to other parameters. This will help in determining a functionally appropriate role for these parameters within the fire detection mechanism, i.e. their appropriate integration in the fire alarm algorithm that is applied on the collected sensors' data.
- The database should be re-organised in a manner that will facilitate application of data analysis of the collected measurements.

It remains to be determined what would be the expected behaviour of the P, CO and CO^2 values during the initial stages of open fire occurrence. This is considered particularly important for pressure variations, considering the very limited and modestly supported evidence in the literature in this regard. Atmospheric pressure levels can change rapidly. When heat enters the atmosphere it creates weather patterns, which could affect the barometric pressure. By forming high pressure and low-pressure systems, fast moving storms are created that can dramatically change the atmospheric pressure in only a few minutes. Even though these might lead to a conclusion that open space pressure measurements are unsuitable for early fire detection, it is advisable that the contribution of the pressure data inputs to a better detection capability of the model, are researched through further experimenting.

In order to determine the behaviour of the fire detection algorithm in situations of non-fire conditions (proneness to false alarms), another dataset from the same controller has been taken on February 3rd 2019. In this case, the time interval that is encompassed by the database entries is much wider, starting at 5.43 AM with the last input at 9 PM. The time intervals between two consecutive measurements were approximately 15 seconds (± 2sec). Measurements include temperature (T), humidity (H), barometric pressure (P), carbon monoxide (CO) and carbon dioxide (CO^2). Again, the variations of the CO^2 measurements have been much larger than it would be expected in normal circumstances, and they have been discarded during the analysis.

By applying the same detection approach, the obtained results have not reported a high-risk fire alarm, as was expected. Because there was not a fire event at this date, this is an indication that the applied detection algorithm is not subjected to reporting false alarms. However, one should consider the fact that the dataset for examining proneness to false alarm has been collected during winter when variations in temperature are not particularly high. If the data had been collected during summer or in a period with increased human activity the results might had been different.

In conclusion to this comparative analysis, it is recommended that further improvements are made to the present approach through experimentation, according to a multi-criteria fire detection procedure that will be built according to the following issues.

1. Determining the sensors' rate of change (slope) for the applied system and evaluating the critical values for fire detection, accordingly.
2. Determine the effective sensor combinations and detection arrays and adjusting the present detection algorithm, accordingly.
3. Further investigate the appropriate fire detection intervals, and the possibility to apply sleeping mode operational mode, without influencing significantly the detection abilities of the system.
4. Determine the appropriate critical values for each of the parameters, according to the input intervals and other conditions.
5. Analyse the occurrence of false alarms and investigate the reasons for their emergence.

3 Conclusions and recommendations

While the current pyric history of the NP does not indicate a general vulnerability of the National Park to forest fire the constantly increasing amount of available fuel and the observed climatic trends provide adequate evidence that wild fires pose a significant threat to the ecological integrity of the ecosystems of the area. The threat is even higher if one considers the fact that the species which constitute the ecosystems in the study area do not possess any fire related traits that would allow them to quickly recover from a forest fire.

An early forest fire detection system should be able to notify firefighters as soon as possible in order to minimize the fire caused damage. Moulianitis et al. (2018) defined the major requirements of an autonomous early forest fire detection system, as follows:

- robust continuous monitoring of the forest area (CMO)
- fast detection of fire (FDF)
- determination of the exact location of fire (ELF)
- early notification (ENO)
- minimization of faulty alarms (FA)

as well as all the following abilities: configurability, interaction ability, dependability, motion ability, perception ability and decisional autonomy, which should be incorporated in these kinds of forest monitoring systems. More specifically, configurability allows a forest system to be configured for every forest environment. Interaction ability enables the secure, non-faulty communication between components of system in order for fire fighters to monitor and specify the location of fire sources on time. Dependability specifies the level of trusting upon the system. Motion ability determines the capability of system to move towards fire, ensuring minimum flight time and consumption. Perception ability determines the level of autonomy on fire detection and its exact location. Decisional autonomy corresponds to the capability of system to verify if an incident of a potential fire ignition is real and not a false estimation so as to notify local fire brigade

Despite the great improvements on the sensitivity of the sensors, the Information and Communication technologies, the artificial intelligence algorithms and technologies, a major drawback of all automatic detection methods is the degree of false alarms. This is particularly true in cases of increased human activities, which often result in elevated temperatures and carbon emissions, and in periods with increased variation in daily temperature. Furthermore, fires often occur as part of agricultural practices, especially during spring and Autumn. An additional piece of information that will classify an area into areas of elevated or low risk is expected to offer an additional insurance that fire alarms will represent actual alarms rather than false. Furthermore, this additional filter will assist the process of spatially distributing the fire fighting forces and patrolling shifts into areas of high risk where a fast initial attack is of crucial importance.

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