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Original scientific paper

DIETARY SALT AS A POTENTIAL DOSIMETER IN RETROSPECTIVE DOSIMETRY

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A b s t r a c t: As a result of the risk that radiological and nuclear disasters and accidents will expose members of the public to unsafe amounts of radiation, numerous emergency dosimetry approaches for triage have been thoroughly explored. The current methods of retrospective dosimetry encompass a variety of biological, physical, and chemical procedures related to the radiation exposure of the human body. Additional items that might be useful as fortuitous dosimeters using luminescence techniques include banknotes, electronic components, table salt, quartz recovered from bricks, and other burnt ceramic materials. In this study, we investigated the usability of the dietary salt supplement for retrospective dosimetry in the dose range related to triage. We studied samples' limit of detection (LOD), dose response, reproducibility, and fading, which are all important elements of the optically stimulated luminescence (OSL) signal and sample's luminescent properties. Measurements were conducted by Riso TL/OSL reader DA-20. The study used potassium chloride tablets and electrolyte powder from different manufacturers that were packaged in standard lightproof containers. The findings of this study demonstrate that these supplements after irradiation provide measurable and satisfactorily reproducible OSL signal. The signal increases linearly with the dose in the triage-related dose range and has low LOD values.

Key words; fortuitous dosimeters; retrospective dosimetry; optically stimulated luminescence (OSL)

ДОДАТОЦИ НА ИСХРАНА КАКО ПОТЕНЦИЈАЛЕН ДОЗИМЕТАР ВО РЕТРОСПЕКТИВНА ДОЗИМЕТРИЈА

А п с т р а к т: Поради ризикот од изложување на широка популација на големи дози јонизирачко зрачење при радиолошки и нуклеарни катастрофи, се истражуваат бројни пристапи за итна дозиметрија со цел брзо спроведување на тријажа. Сегашните методи на ретроспективна дозиметрија опфаќаат различни биолошки, физички и хемиски методи чија крајна цел е да го утврдат степенот на изложеноста на јонизирачко зрачење. Материјалите кои можат да се користат при испитувањето со физички методи на луминисценција се банкнотите, електронските компоненти, готварската сол, кварцот извлечен од тули и други топлински обработени керамички материјали. Во овој труд се истражува применливоста на додатоци на исхраната кои содржат соли за употреба во ретроспективна дозиметрија во опсегот на дози поврзани со тријажа. Целта на истражувањето е да се утврдат лимитот на детекција, одговорот на доза, повторливоста и стареењето на сигналот. Мерењата се извршени со читачот Riso TL/OSL DA-20. Користени се калиумов хлорид и електролити од различни производители. Резултатите од ова истражување покажуваат дека испитуваните материјали по изложеноста на јонизирачко зрачење обезбедуваат мерлив и задоволително повторлив сигнал. Интензитетот на сигналот се зголемува линеарно со дозата во дозниот опсег поврзан со тријажа и има низок лимит на детекција.

Клучни зборови: дозиметри; ретроспективна дозиметрија; оптички стимулирана луминисценција (OSL)

1. INTRODUCTION

Numerous emergency dosimetry techniques for triage have been thoroughly studied as a result of the concern that radiological and nuclear catastrophes and accidents will expose members of the public to dangerous levels of radiation. Various biological, physical, and computational techniques

related to the radiation exposure of the human body are included in the current methods of retrospective dosimetry [1].

Banknotes, chip cards, dust on coins, tobacco, clothing, common table salt, salty foods like crackers and snacks, quartz recovered from bricks, and other fired ceramic materials are additional items that might be useful for testing with luminescence techniques [2, 3]. The category of personal items might include medications and nutritional supplements [4]. Numerous studies were done to determine their dosimetry potential.

In this study, we studied the dietary salt supplement's applicability for retrospective dosimetry in the dose range associated with triage. OSL was chosen as a measurement method. Our attention was drawn to crucial aspects of the OSL signal in the samples, including sensitivity variations over the course of multiple readings, dose response, LOD, and fading.

MATERIALS AND METHODS

Materials used for this study, including potassium chloride and electrolyte, were purchased at a local pharmacy. Potassium chloride was in the form of tablets of different shapes and sizes, while electrolyte was in the form of a powder. They were enclosed in common lightproof pharmaceutical packaging. All the data were taken from the patient information leaflets or packaging. Table 1 provides a list of the materials used, with details on their composition.

The size and shape of most of the tablets in their intact form were not suitable for OSL measurements. The tablets of all used materials were crushed using a mortar and a pestle. The powder was not sieved and thus contained grains of different size. Powder aliquots for measurements were created by covering cups used within the OSL instrumentation with a thin layer of the powder. The cups used are with an inner diameter of 8 mm. The weight of the powder portions spread on the cups was 9.8 – 10.2 mg. The preparation was performed in darkroom conditions.

Measurements are performed by Riso TL/OSL reader DA-20. The optical stimulation was carried out with blue LEDs with a peak emission at 470 nm. Samples were stimulated and read using continuous-wave OSL, in which the stimulation light intensity is kept constant and the OSL signal is monitored continuously throughout the stimulation period. The light intensity was 50 mW/cm^2 at the sample position. The stimulation lasting 60 s was performed at room temperature. All results are obtained as the mean value of the integral in the range from 0 to 1.5 seconds, on 5 samples. Preparation was performed in dark room conditions, as well as the storage of samples. This study was performed on Potassium chloride tablets and powder Electrolyte from different manufacturers, enclosed in common lightproof packaging. The tablets were not acceptable for OSL measurement due to their size and shape in their intact condition. With the aid of a mortar and pestle, the tablets were broken up. The powder had not been sieved, thus it contained granules of all sizes.

Table 1

List of the medications and food supplements with details on their composition

Dietary salt supplement Brand name (manufacturer)	Ingredients
Potassium chloride Belupo	Potassium chloride 500 mg Lactose monohydrate 19.75 mg
Potassium chloride JADRAN galenski laboratorij - JGL	Potassium chloride 500 mg Lactose hydrate 25 mg
Electrolyte (Electrolyte 1) Erba Vita Nature in Science	Maltodextrin, Calcium citrate, Sodium bicarbonate, Fructose, Orange aroma, Sodium chloride, Lemon acid, Magnesium carbonate, Silicon dioxide, L-ascorbic acid (Vitamin C), Betacarbotene, Sucralose, Sodium citrate, Riboflavin (Vitamin B6), Peroxide hydrochloride (Vitamin B1), Cyanocobalmin (Vitamin B12)
Hidraton neo Bioecolians ® (gluco-oligosaccharide) (Electrolyte 2) DS natural	Bioecolians (gluco-oligosaccharide), Dextrose, Sodium, Chlorine and Potassium

RESULTS AND ANALYSIS

OSL signal

Figure 1 shows the OSL signal obtained after irradiation with different doses. After illumination and test irradiation with dose of 1 Gy, all materials described in Table 1 displayed a clear OSL signal. A similar response is observed in KCl preparations, while in electrolyte mixtures there is a greater difference due to their complex composition. In KCl preparations, the intensity of OSL decreases more slowly and a significant luminescent signal could be observed even after 5 s of illumination.

The specific luminescence values $C_{specific}$ (counts·mg^{-1}·Gy^{-1}) and LOD are given in Table 2 for all used materials. LOD is calculated according to the method reported by Geber-Bergstrand et al. [5, 6]. This method considers the uncertainty of the calibration curves of the dose response.

$$\mathrm{LOD} = \frac{S_0}{k} + 3\left(\sqrt{\left(\frac{\sigma_s}{s_0}\right)^2 + \left(\frac{\sigma_k}{k}\right)^2} \cdot \frac{s_0}{k}, \qquad (1)$$

where S_0 is the average number of counts of the zero-dose samples, k is the slope of the calibration curve, σ_s is the standard deviation of S_0, and σ_k is the standard deviation of k.

LOD was determined using data from OSL measurements on non-irradiated samples. For potassium chloride samples, values of 171 Gy and 593 Gy were obtained, while values of 4.3 mGy and 1.4 mGy were obtained for electrolyte samples.

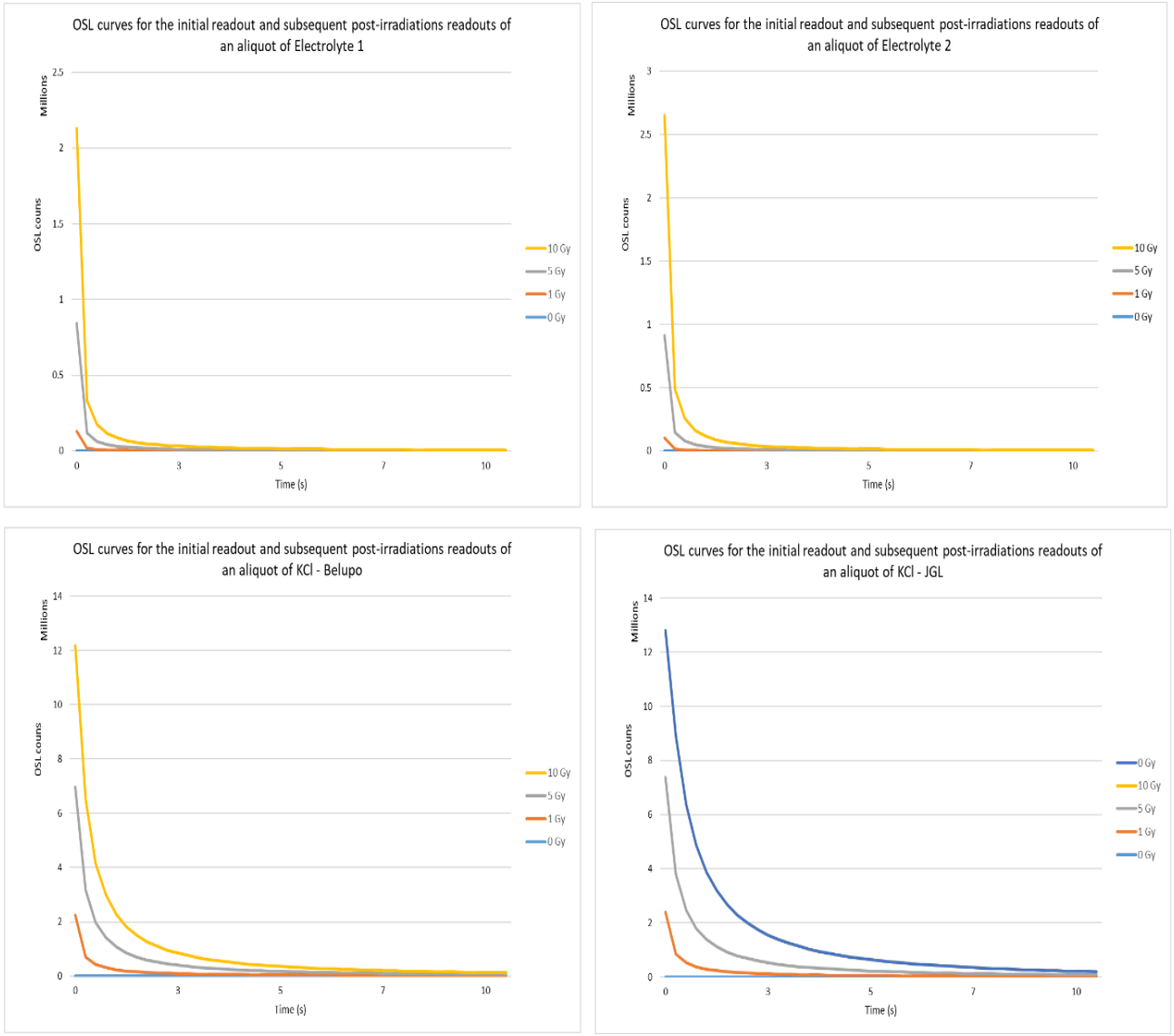

Fig. 1. OSL responses

Table 2

Specific luminescence and LOD

Sample	Specific luminescence, C_{specic} (counts / mg · Gy)	LOD
KCl – Belupo	416376±34342	171 μGy
KCl – JGL	441032±50903	593 μGy
Electrolyte 1	19365±5506	4.3 mGy
Electrolyte 2	19562±21884	1.4 mGy

Dose-response

The OSL response of samples exposed to doses of 0, 1, 2, 3.5, 5, 6.5, 8, and 10 Gy was studied, measuring 5 samples of each material (Figure 2).

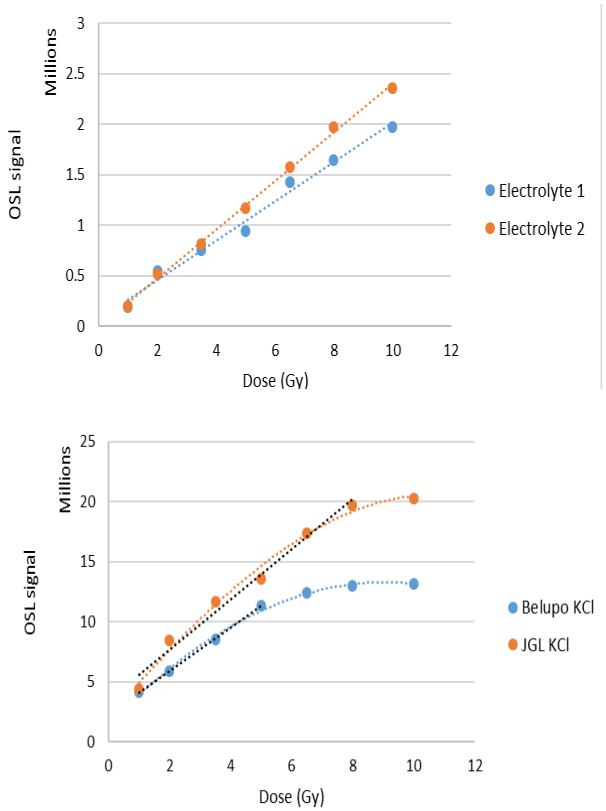

Fig. 2. Dose-response and linearity

According to the results for potassium chloride dose-response test, linearity is seen up to 5 Gy for JGL sample and up to 8 Gy for Belupo sample. OSL signal to dose linearity in the electrolyte was attained up to 10 Gy.

Reproducibility

For the aim of measuring reproducibility, aliquots of each sample were exposed to radiation at a dose of 5 Gy and read ten times in a row. The OSL signals were normalized to the value found for the first cycle. The dose response must be determined using a Single-Aliquot Regenerative-dose methodology for materials with a high coefficient of reproducibility (>1.1) [8]. In the examined potassium chloride, the reproducibility was obtained from 1.1 to 1.3, while in the case of electrolytes it ranges up to 2.9 (Figure 3).

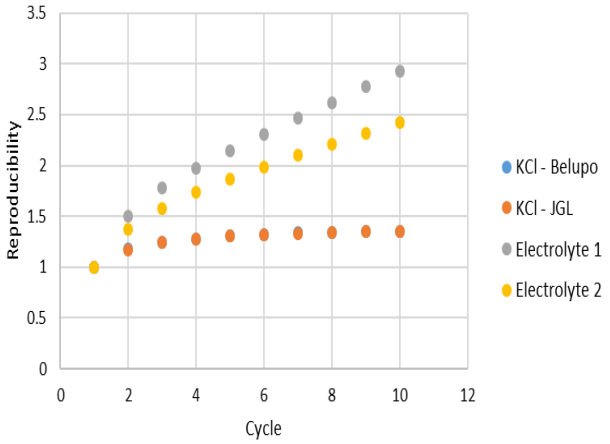

Fig. 3. Reproducibility of repeated measurements

However, additional illumination can reduce this factor, which is most likely due to undischarged loops. This can also be explained by the phenomenon named as the regeneration effect characteristic of salt compounds [9]. However, by adding another illumination step with 100% power for 60 s after the reading, the coefficient drops below 10%.

Fading

Over a seven-day period, we identified fading of the OSL signal (Figure 4). After one week, the OSL signal decreased to about 80% of its initial value obtained right after irradiation. The measurements for dose reconstruction ought to be performed as soon as possible after radiation exposure.

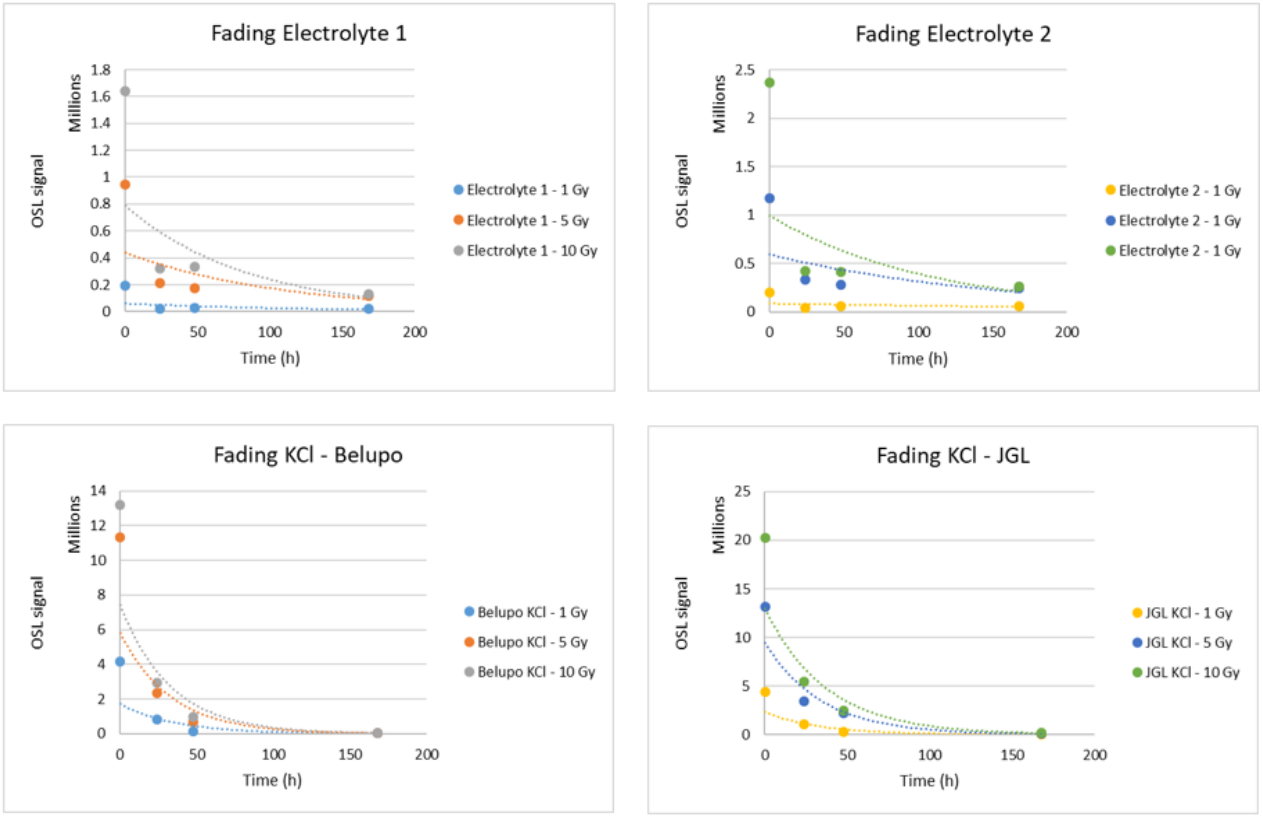

Fig. 4. Fading of OSL signal

CONCLUSION

In this study we performed measurements on potassium chloride and electrolyte by OSL in order to determine crucial aspects of the OSL signal including sensitivity variations over the course of multiple readings, dose response, LOD, and fading. Using data obtained from OSL measurements on non-irradiated samples, the LOD for potassium chloride and for electrolyte samples was determined. Moreover, measurements were done on samples exposed to doses of 0, 1, 2, 3.5, 5, 6.5, 8, and 10 Gy, and their response to optical stimulation was investigated. From the dose-response test, linearity for potassium chloride is observed in aliquots irradiated with doses of up to 5 Gy for one and up to 8 Gy for the other sample. In the electrolyte, linearity of OSL signal vs. dose was obtained in aliquots irradiated with doses of up to 10 Gy. Regarding the interpretation of the subsequent dosimetry experiments that were based on the repeated usage of individual aliquots, it was crucial to examine the reproducibility of the OSL signals. Because of high coefficient of reproducibility the dose response must be determined using a Single-Aliquot Regenerative-dose methodology [7]. In the examined potassium chloride, the reproducibility was obtained in the range 1.1 -1.3, while in the case of electrolytes it ranges up to 2.9. We observed fading over a period of seven days. The OSL signal dropped to about 80% of its initial value after one week. Ideally, the measurements for dose reconstruction should be carried out within a few days of radiation exposure. The investigated materials can be applied for dose determination in nuclear incidents as retrospective dosimeters in the first days after the accident. In addition, the luminescent responses to combined heat and light stimulation that can improve some of the key luminescence parameters should be investigated.

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Original scientific paper

EVALUATING THE EFFECTIVENESS OF METEOROLOGICAL MEASUREMENTS IN ASSESSING AIR POLLUTION IN THE REPUBLIC OF NORTH MACEDONIA

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A b s t r a c t: This study examines the effectiveness of meteorological measurements in assessing air pollution in the Republic of North Macedonia. The study is based on measurements of air pollutants such as particulate matter (PM), carbon monoxide (CO) and nitrogen dioxide (NO_2). Meteorological measurements, such as temperature, wind speed, and precipitation, have been used in the past to measure air pollution levels. However, the accuracy of these measurements has not been extensively studied. The current research investigates the accuracy of meteorological measurements in assessing air pollution in North Macedonia by analyzing both long-term and short-term air quality data. The results of this study will provide insight into the reliability of meteorological measurements in assessing air pollution, and the potential for using these measurements to better understand the air quality in North Macedonia.

Key words: particulate matter; air quality; meteorological measurements; air pollution

АНАЛИЗА НА ВЛИЈАНИЕТО НА МЕТЕОРОЛОШКИТЕ ФАКТОРИ ВРЗ ЗАГАДУВАЊЕТО НА ВОЗДУХОТ ВО РЕПУБЛИКА СЕВЕРНА МАКЕДОНИЈА

А п с т р а к т: Во трудот се анализира влијанието на метеоролошките фактори врз загадувањето на воздухот во Република Северна Македонија. Во овие истражувања се мерени нивоата на загадувачите на воздух како што се цврстите честички (PM), јаглеродниот моноксид (CO) и азотниот диоксид (NO_2). При анализите се земени предвид и влијанијата на метеоролошките фактори како што се температурата, брзината на ветерот, дождовите, кои отсекогаш се користат како параметри за мерење на нивото на загадување на воздухот. Во овој труд преку статистичка анализа на податоците за квалитетот на воздухот е направена процена колку овие параметри влијаат врз квалитетот на воздухот. Резултатите од ова истражување можат да се применат како влезни параметри на доверливоста на метеоролошките мерења за процена на загадувањето на воздухот и како потенцијал за користење на овие мерења за подобра анализа на квалитетот на воздухот во Северна Македонија.

Клучни зборови: цврсти честички; квалитет на воздух; метеоролошки фактори; загадување на воздух

1. INTRODUCTION

Air pollution is one of the most severe environmental risks to human health. In cities, primary air pollutants include particulate matter (PM), sulphur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), nitrogen oxides (NO_X), and volatile organic compounds (VOCs) [1]. Studies conducted by [2] and [3] demonstrate that increased levels of air pollution (including O_3, PM and SO_2) are linked to increased mortality rates. According to the report from the European Environment Agency [4], air pollution is a major cause of death in many European countries, resulting in more than 400,000 premature deaths. In addition, these pollutants can damage monuments and artwork, particularly those located in city centers [5].

Meteorological studies can be used to assess the impact of air pollution on the atmosphere, measuring the levels of air pollutants and how they affect air quality, temperature, humidity, visibility and wind speed. Similarly, green infrastructure studies can be used to assess the impact of air pollution on land use and the environment, analyzing how air pollutants affect soil, vegetation, and water resources. Common sources of air pollution include burning of fossil fuels, industrial processes, agricultural activities, and transportation, releasing pollutants such as carbon dioxide, sulfur dioxide, nitrogen dioxide, particulate matter, and volatile organic compounds into the air. These pollutants have the potential to alter local weather patterns, reduce visibility, and cause acid rain, as well as contribute to the formation of smog, which can lead to respiratory problems in people

Air pollution is especially high in urban environments due to global urbanization and the construction of new buildings in major cities, which leads to an increase in temperature and consequently, an increase in air pollution [6, 7]. This phenomenon, known as the urban heat island (UHI) effect, has been explored by many authors. According [8], city temperatures can rise by 2°C to 8°C, while newer research [9] suggests a temperature increase of 5°C to 15°C. In the paper [10] estimates that by 2030, 61% of the world's population will live in cities, and the UHI effect will be more intense due to deforestation and global warming. In order to address urban environmental problems, some authors have studied the effects of vegetation, particularly trees, on cooling urban air, shading buildings, and absorbing gaseous air contaminants [11, 12]. An innovative approach to mitigating air pollution is the implementation of green walls, green facades, and green buildings. The effectiveness of this approach has been confirmed in various cases applied in Switzerland, Sweden, UK, USA, and Spain [13]. The benefits of implementing vertical green walls and green roof surfaces on building facades include improved thermal characteristics of the objects, reduced noise levels, and reduced energy requirements for the facilities [14]. The impact of vegetation on the thermal environment of buildings was examined in the studies of [15] and [16]. In [17], it was quantified that by using green roofs in Tokyo the average ambient temperature can be lowered by 0.3°C, while [18] estimated a temperature reduction of 0.1°C. In [11], experiments were conducted to measure the influence of tree planting and re-roofing on ambient temperatures and air pollution, which concluded that the ambient temperature can be reduced by up to 3°C, and the air around the building can be cooled through the implementation of trees combined with cool roofs. The influence of garden roofs on air temperature mitigation was also investigated in [19], which concluded that garden roofs are more effective in reducing heat gain in summer than heat loss in winter. Air pollution mitigation by the implementation of green walls and green roofs was investigated in [20], while [21] evaluated different arrangements of trees on pollution dispersion. Finally, [22] suggested a Computational fluid dynamics (CFD) model for predicting pollutant levels and distribution, which was validated through a test case on a wind tunnel urban canyon in Belgium, using wind catchers to increase the dispersion process of air pollution removal.

For several years, the city of Skopje has been experiencing an issue with air quality [23]. This is due to its geospatial position, coupled with the worsening climate conditions in the winter months. The rapid urbanization and population growth have added to the energy demands of the city, particularly the heat demand in the period from November to April. The geographical position of Skopje, the capital of North Macedonia, in the Vardar river valley and its local weather conditions have caused the pollutants to build up in the city. Additionally, the city of Skopje stretches for more than 23 km, but it is only 9 km wide. For years, Skopje has had a bad reputation for the enormous exceeding concentration of PM in the air throughout the whole [24]. It is interesting to observe that the concentration of PM2.5 and PM10 in Skopje is much higher during the night. In [25], it was reported that the concentration of PM2.5 is 18% higher, while the concentration of PM10 is almost 20% higher during the night compared to the daytime periods. The observed problems as well as the changes caused by the COVID-19 pandemic were the major drivers for conducting the study presented in this paper.

This paper examines the effectiveness of meteorological measurements in assessing air pollution in North Macedonia. It evaluates the accuracy of the meteorological measurements, their ability to detect changes in air pollution levels, and their potential to be used as a tool for policy decisions. The paper also evaluates the various factors that influence the accuracy of the measurements, including seasonal weather patterns, topography, and other regional factors. Finally, the paper provides recommendations for the optimal use of meteorological measurements in air pollution monitoring and assessment in the region.

2. MEASUREMENT SYSTEM DESCRIPTION

The position of the sensor nodes in 2018 were located as depicted in Figure 1 (the sensor nodes are marked as magenta), while the positions of the sensor nodes in 2019 were changed (the sensor nodes are depicted in yellow). Sensor node 1 is now located close to the pedestrian pavement, while sensor node 2 is placed near a small green area, which is part of the building patio. Sensor node 3 is relatively closer to the secluded green area. The green wall structure consisting of two rows of hedera helix plants was installed in the beginning of the measurement setup and was planted during the spring period. The sensor nodes were placed on a platform, where two photovoltaic panels were already installed. The measurement results considering the impact of the green wall structure on air quality improvement was presented in [25]. In order to identify the influence of the green areas, traffic and movement of people, the different positions of the sensor nodes were chosen.

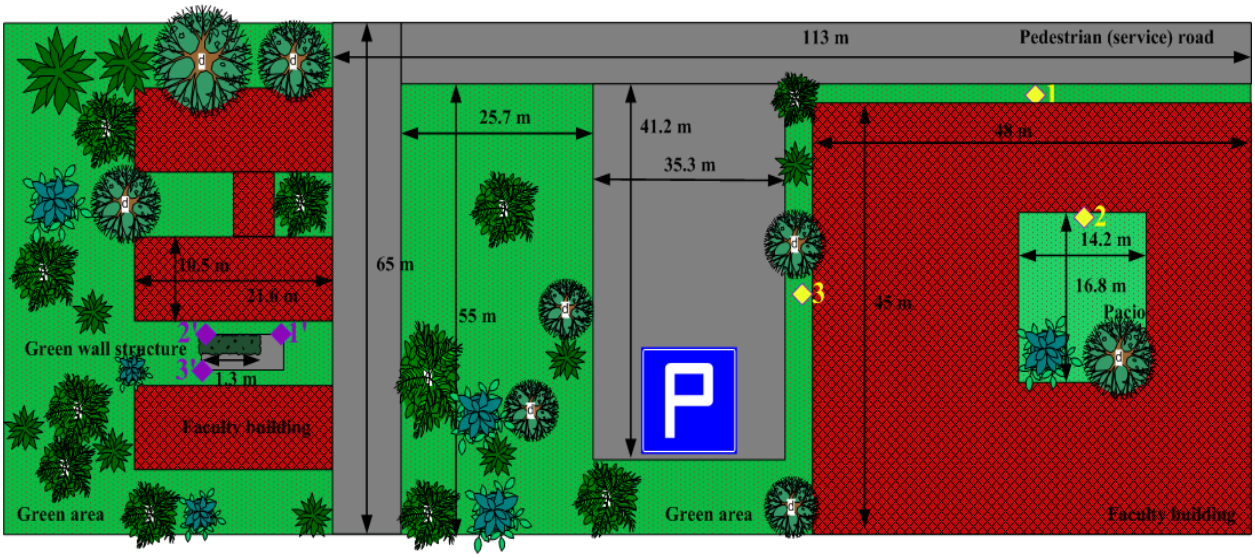

Fig. 1. Position of the sensor nodes

A wireless sensor network-based measurement system was initially developed, comprised of PM and gas sensors for monitoring air quality parameters. The monitoring system consists of a few sensor nodes, each containing four sensors and a Wi-Fi module integrated onto a single-board controller. Each node is able to measure PM2.5, PM10, CO, and NO_2 concentrations. The SDS011 is an integrated device which contains sensors for measuring PM2.5 and PM10 concentrations between 0.3 μm and 10 μm. The MiCS-4514 sensing unit also integrates two sensors, one for CO and one for NO_2 measurements. The main features of these sensing units are listed in Table 1.

The controller plays a vital role in pre-processing the data before it is sent to the network. It has a wide range of applications, from low-power sensor networks to high-power applications such as music streaming and voice encoding. The most significant features of the controller are detailed in Table 2.

The Wi-Fi modules that are integrated part of the sensor nodes, send data to the closest routers, which are located in the Faculty building. The collected data from the closest routers are uploaded on an open platform [26] and can be monitored on-line or downloaded for additional analyses.

T a b l e 1

Main characteristics of the sensing units

	SDS011	MiCS-4514
Measurement parameters	PM2.5, PM10	CO, NO_2
Supply voltage	5 V	4.9 V – 5.1 V
Operating temperature range	–20°C –50°C	–30°C –85°C
Range	0.0 – 999.9 μg/m^3	/
CO detection range	/	1 – 1000 ppm
Sensing resistance in air	/	100 – 1500 kΩ
Maximum working current	220 mA	

T a b l e 2

Main characteristics of the controller

	Controller
Measurement parameters	*EPS32*
Supply voltage	2.7 V – 3.6 V
Operating temperature range	–40°C –85°C
Module interface	SD Card, UART, SPI, I2C, Motor PWM
Wi-Fi frequency range	2.4 GHz – 2.5 GHz

MEASUREMENT RESULTS

The paper analyzes the pollution in Skopje in the period of May 2018 – January 2023. Due to some technical issues the data for the pollution is missing in the period of 21.09.2018 – 26.10.2018 and 19.02.2019 – 13.03.2020. The data is collected from three sensors located in the campus of the technical faculties at Ss. Cyril and Methodius University in Skopje. All of the three sensors collect data for the concentration of PM2.5, PM10, CO, and NO_2, the average values of the concentrations recorded by the three sensors for all pollutants were analyzed. The concentration of air pollutants by month are considered. The results suggest that the data for PM2.5 and PM10 is not normally distributed (Kolmogorov-Smirnov test reports *p*-value = 0.000), even more, the data is right-skewed with positive kurtosis. The distributions of CO and NO_2 are also not normal as Kolmogorov-Smirnov test reports *p*-value = 0.000. The descriptive statistics for the pollution by months is given in Tabe 3 and Table 4.

The histograms for each variable by months are given in

It is clear that the most polluted months with respect to PM2.5 and PM10 are the winter months, more precisely December and January. At the same time, the smallest concentration of PM2.5 and PM10 is reported during summer, i.e., from May to August. This is clearly evident in Figure 2a and b. If similar analysis is done for CO and NO_2, the variation is not that obvious. Still we observe that the highest concentration of CO is reported in spring (from February to April), and the lowest in June and July. When NO_2 is concerned, the lowest concentration is reported in May, and highest during winter months (Table 4 and Figure 2c and d).

T a b l e 3

Descriptive statistics for the pollutants PM2.5 and PM10 by months in the studied period

Month	PM2.5				PM10			
	Range		Mean	St.dev.	Range		Mean	St.dev.
	min	max			min	max		
Jan.	0.6	305.9	33.7	36.8	0.7	372.0	41.8	45.3
Feb.	0.5	104.0	18.9	16.3	0.5	128.5	23.6	20.3
March	1.1	67.3	11.5	9.1	1.4	86.4	14.5	11.0
April	0.7	25.2	5.8	3.4	0.8	30.5	7.4	4.0
May	0.3	22.4	3.7	2.1	0.5	32.9	6.3	3.9
June	0.8	22.7	3.7	2.3	1.1	31.9	5.4	3.0
July	0.9	16.0	4.6	2.3	1.25	20.9	6.0	2.7
Aug.	1.3	23.0	5.0	2.1	1.7	27.1	6.8	3.0
Sep.	0.5	84.6	5.4	3.6	0.8	134.8	7.7	5.5
Oct.	0.4	87.6	10.3	8.9	0.7	107.0	13.2	10.8
Nov.	0.5	123.4	20.9	13.2	0.8	138.9	27.4	17.2
Dec.	0.8	162.4	30.3	26.6	1.2	219.2	41.8	38.3

T a b l e 4

Descriptive statistics for the pollutants CO and NO_2 by months in the studied period

Month	CO				NO_2			
	Range		Mean	St.dev.	Range		Mean	St.dev.
	min	max			min	max		
Jan.	1.8	7.7	3.9	1.1	18.0	21.6	20.4	0.4
Feb.	2.2	11.9	4.8	1.6	18.5	21.7	20.30	0.4
March	2,9	12.9	5.8	1.7	15.9	21.2	20.2	0.4
April	3.2	9.37	4.8	0.9	18.0	21.0	19.9	0.4
May	1.5	6.6	4.1	1.0	3.1	20.3	17.8	3.7
June	1.4	6.4	3.7	1.1	5.7	20.1	18.6	1.8
July	1.4	7.0	3.7	1.3	13.9	19.8	18.8	0.5
Aug.	1.8	6.5	3.8	1.2	16.0	19.7	18.8	0.5
Sep.	2.1	6.9	3.9	0.9	17.3	20.1	19.1	0.4
Oct.	1.9	7.4	3.9	0.9	18.7	20.5	19.6	0.3
Nov.	1.9	7.9	3.9	1.3	19.0	20.8	19.8	0.3
Dec.	1.9	9.7	4.1	1.3	16.9	21.3	20.3	0.4

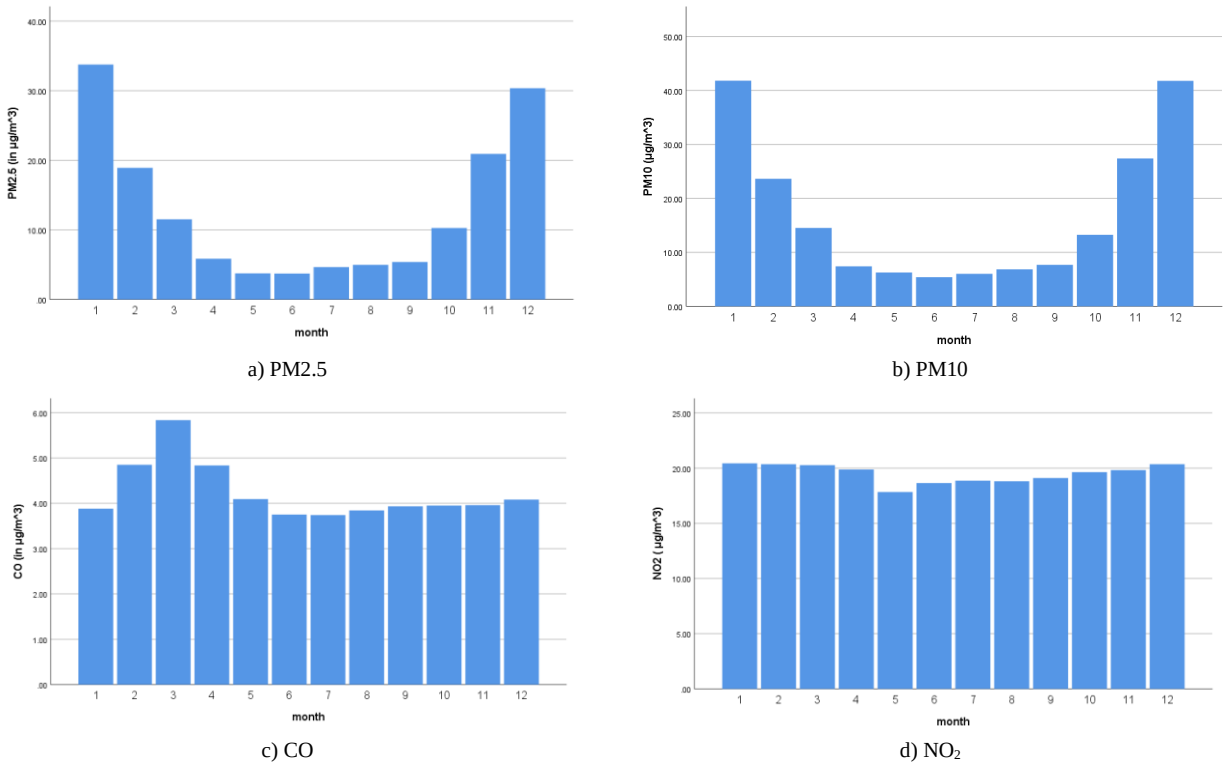

Fig. 2. Average concentration of the pollutants PM2.5, PM10, CO, and NO_2 in the observed period

In order to see if these visually detected differences are statistically significant hypothesis tests were performed. Each test the null-hypothesis "There is no difference in the concentration of the pollutants (PM2.5, PM10, CO, and NO_2, respectively) between months", against the alternative hypothesis "There is a difference in the concentration of the pollutants (PM2.5, PM10, CO, and NO_2,

respectively) between months". We set the significance level $\alpha = 0.05$. As the data for each of the considered pollutant is not normally distributed we perform the Kruskal-Willis [27] hypothesis test to see if the difference between the months is statistical significant. For all four pollutants the corresponding *p*-value is 0.000, which means that the null hypothesis H_0 is rejected. To locate the difference, we perform post hoc tests. The results of the post hoc test are presented in Table 5. Namely, in Table 5 the corresponding cell is marked if there is no significant difference between those two months. Different color is used for different pollutant(s).

Table 5

There is no statistically significant difference in the concentration of the corresponding pollutant(s) between months

PM2.5	PM10	CO	NO_2	PM2.5&10	PM&CO	All

	Jan.	Feb.	March	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
Jan.												
Feb.												
March												
April												
May												
June												
July												
Aug.												
Sep.												
Oct.												
Nov.												
Dec.												

The correlations between air pollutants and meteorological factors for each month are displayed in Table 6. This study considers wind speed, precipitation, humidity, visibility, and temperature as its meteorological factors. It is found that the strongest correlation between PM2.5 and PM10 concentration and the wind speed is confirmed. A slightly stronger correlation between the PM concentrations and the real feel temperature, as opposed to the actual temperature, is also reported. However, very week correlations are noticed between PM concentrations and the humidity. All the correlation coefficient presented in Table 6 are statistically significant.

Table 6

Correlations between air pollutants and meteorological factors by months

	PM2.5	PM10	CO	NO_2	Humidity (%)	Precipitation (mm)	Visibility (km)	Wind speed (km/h)	Temperature (°C)
PM2.5	1	0.991	–0.202	0.211	0.280	–0.050	–0.044	–0.218	–0.408
PM10	0.991	1	–0.206	0.200	0.261	–0.061	–0.023	–0.219	–0.391
CO	–0.202	–0.206	1	0.342	–0.016	–.006	–0.032	–0.034	–0.299
NO_2	0.211	0.200	0.342	1	0.334	0.046	–0.125	–0.128	–0.539

CONCLUSION

This paper has analyzed the pollution in Skopje in the period of May 2018 to January 2023. The data was collected from three sensors located in the campus of the Faculty of Electrical Engineering and Information Technologies at Ss. Cyril and Methodius University in Skopje, North Macedonia, and the average concentrations of PM2.5, PM10, CO and NO_2 were recorded for each month. The collected data was not normally distributed, and was right-skewed with positive kurtosis. Although the data was missing for some periods due to technical issues, the results of this study are still important in understanding the air pollution levels in Skopje. In this paper, wind speed, precipitation, visibility, and temperature were examined as meteorological factors. It was found that the strongest correlation between PM2.5 and PM10 concentrations and wind speed was confirmed. Additionally, a negative correlation between the PM concentration and wind speed was verified in all three locations. There was a slightly stronger correlation between the PM concentrations and the "real feel" temperature. However, insignificant correlations were noticed between the PM concentrations and the humidity. It is important to take measures to reduce air pollution in the city in order to protect public health. It is hoped that more comprehensive data will be collected in the future to further our understanding of air pollution in this area. The findings of this paper are useful for the development of policy initiatives to reduce air pollution and improve air quality in Skopje.

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Original scientific paper

DAB+ RADIO SERVICES WITH QUALITY SUPPORT IN NORTH MACEDONIA

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A b s t r a c t: The digitization of radio broadcasting has a long history and has been under active consideration as a project for at least 40 years. This paper will provide a brief historical development of digital radio, an overview and analysis of European and world trends today, as well as additional services offered by the DAB+ system. Furthermore, the paper includes the advantages and challenges of the DAB+ standard compared to FM analogue radio and Internet radio listening technologies, which countries have developed the standard and their planning approach. The overall development experience from the environment and the world will serve for the innovative and technological possibilities of digital radio for the future development in Macedonia. The main focus of the paper is the preparation of: DAB+ frequency planning in Macedonia, other planning and use cases, as well as a pilot project for the implementation of DAB+ in Macedonia. Our country is in the experimental phase and preparation for the regulation and introduction of DAB+ digital radio. It is necessary to form an interdepartmental working group (JP Macedonian Broadcasting, Agency for Electronic Communications (AEC), Ministry of Information Society and Administration (MISA), Agency for Audio and Audio-Visual Media Services of the Republic of Macedonia (AAAMS), Macedonian Radio Television (MRTV), private broadcasters, etc.) that will prepare a Strategy for the Introduction of DAB+ digital radio – each in its own part, and thus a change in the Law on electronic communications.

Key words;; DAB; DAB+; FM; IP; HE-AAC v2; SFN; OFDM

УСЛУГИ НА РАДИО DAB+ СО ПОДДРШКА ЗА КВАЛИТЕТ ВО СЕВЕРНА МАКЕДОНИЈА

А п с т р а к т: Дигитализацијата на радиоемитувањето има долга историја и како проект е под активно разгледување најмалку 40 години. Овој труд дава краток историски преглед на развојот на дигиталното радио, преглед и анализа на европските и светските трендови денес, како и дополнителните услуги кои ги нуди системот DAB+. Во трудот исто така се разгледуваат предностите и предизвиците на стандардот DAB+ во споредба со аналогното FM-радио и Интернет-технологиите за слушање радио, како и кои земји го развиле стандардот и нивниот начин на пристап кон планирањата. Целокупното развојно искуство од околината и светот ќе послужи за идниот развој на иновативните и технолошки можности на дигиталното радио во С. Македонија. Главен фокус на трудот е претставување на планирање на DAB+ фрекфентнции во С. Македонија, други планирања и случаи на користење, како и пилот-проект за имплементација на DAB+ во С. Македонија. Нашата држава се наоѓа во експериментална фаза и подготовка на регулација и воведување на дигиталното радио DAB+. Потребно е формирање меѓуресорска работна група (ЈП Македонска радиодифузија, АЕК, МИОА, АВМУ, МРТВ, приватни радиодифузери и др.) која ќе подготви стратегија за воведување дигитално радио DAB+ – секој во својот дел, а со тоа и промена на Законот за електронски комуникации.

Клучни зборови: DAB; DAB+; FM; IP; HE-AAC v2; SFN; OFDM

1. INTRODUCTION

Digital technology for the development of radio transmission begins with the DAB system which was developed in 1981 by the Institut für Rundfunk Technik (IRT). Project Eureka 147 was established in 1985 by the European Union to encourage a bottom-up approach to technological development and to strengthen the competitive position of European

companies on the world market. The Eureka 147 consortium was founded in 1987 with 16 partners from the EU, and Germany, France, the Netherlands and the UK are the holders. The Eureka 147 standard was defined in 1993 with International Telecommunication Union (ITU) recommendations published in 1994 and an initial ETSI standard published in 1995. Eureka shut down the Eureka 147 project on January 1, 2000. WorldDAB was established in 1995 to encourage international cooperation and coordination to introduce DAB to the consumer market. Technical work previously carried out by Eureka 147 is now carried out within the Technical and Commercial Committees of WorldDAB. The DAB/DAB+ is defined by international ITU recommendations, European Telecommunications Standards Institute (ETSI), European Committee for Electrotechnical Standardization (CENELEC), International Electrotechnical Commission (IEC) standards and national standards (e.g. Australian, British standards for receivers) [1–4].

WorldDAB, the organization responsible for DAB standards, released DAB+ the major upgrade to the DAB standard in 2006, when the HE-AAC v2 audio coded (also known as AAC+). The AAC+ uses a modified discrete cosine transform (MDCT) algorithm. The new standard, called DAB+, adopted both the MPEG Surround audio format and stronger error correction coding in the form of Reed-Solomon coding.

DAB+ is standardized by the European Telecommunications Standards Institute (ETSI) [4]. As DAB is not backwards compatible with DAB+, older DAB receivers cannot receive DAB+ broadcasts. However, DAB receivers that will be able to receive the new DAB+ standard via an upgrade went live and on sale in July 2007 [5–10].

Existing analog AM and FM systems suffer from inherent shortcomings and neither can offer uniform reception quality across the entire coverage area. AM radio reception is limited by bandwidth limitations that limit sound quality and by interference from other co-channel and adjacent broadcast channels, and this is particularly problematic during night-time hours. Analogue FM terrestrial broadcasting has been pushed to its limits in terms of technology and programming, and the available frequencies have already been allocated. There is almost no room for new channels, services and technical innovations. The FM radio market has become a limiting field, thus limited to current broadcasters. This imbalance at the expense of commercial providers is under criticism because historically based, public broadcasters have more FM frequencies available to them. The DAB+ puts an end to this and revives competition for the benefit of the listening public. The DAB+ is the perfect complement to the Internet and vice versa, but the Internet streaming platform is not a substitute for DAB+. Despite the Internet, terrestrial transmission of radio programs allows their anonymous and free use without audio restrictions.

DAB+ is a synonym for diversity, quality and innovation of the programs, and at the same time it provides innovative radio stations with practically unlimited opportunities for their program development and for new programs of special interest. Another aspect of AM and FM analog transmissions is the inefficient use of spectrum (relative to what is possible using digital technology). There are many ways in which digital radio systems can improve upon analog systems such as [3, 5]:

• Digital signals are more robust than analogue and can be transmitted successfully at lower transmitter powers.

• Digital systems using coded multicarrier modulation offer much improved reception on mobile car radios and portables.

• Advanced digital compression techniques enable low bit rates to be used successfully, whilst still producing sound of near CD quality. This makes digital systems more spectrum efficient.

• The digital bit-stream can be used for transmitting both audio and data.

• A digital radio is much easier to use/tune than an AM/FM radio.

• The data capability of digital radio can be used directly or combined with activities such as Internet radio.

According to the latest research and studies with different scenarios in Europe and the wider world, using three different transmission platforms: FM, DAB+ and IP-DAB+ digital radio is the most affordable way to broadcast radio [7–5].

While traditional receivers are still the dominant device for listening to radio, using a smart radio as a receiver – Hybrid Radio is the Future. Hybrid radio seamlessly combines radio broadcasting and the Internet. A broadcast signal (FM, HD, DAB, DAB+) continues to transmit audio (and some data), but a radio with an Internet connection (WiFi, 3G, 4G, LTE, 5G) can seamlessly connect to the station

for multimedia and interactivity. Hybrid radio is evolving with standards and better combines broadcast with the radio that the Internet is creating. At the same time, the range of listening options, whether involving mobile, fixed or portable devices, smart Hybrid radios has expanded significantly, especially in cars. Music, streaming platforms, podcasts and other formats that aren't radio in the traditional sense are all competing for listeners [7, 12, 13].

Today, DAB+ has established itself as a new standard for radio transmission throughout Europe, and even more widely around the world – also called green radio. In terms of radio broadcasting, studies have shown that DAB+ has the lowest energy consumption, and a hybrid approach of DAB+ and IP will achieve the greatest energy savings [14, 15].

2. DAB+ IN EUROPE AND THE WORLD TODAY

The DAB+ system is a sound, video and data broadcasting system with high efficiency and power. It uses industry standard audio and video encoding techniques to remove redundancy from the source signals, it then applies closely controlled redundancy to the signal to be transmitted to provide strong error protection. The transmitted information is spread in both the frequency and time domains so that the defects of channel distortions and fades can be eliminated from the recovered signal in the receiver, even when working in conditions of severe multi-path propagation, whether stationary or mobile. Efficient spectrum utilization is achieved by interleaving multiple programmed signals and, additionally, by a special feature of frequency re-use, which permits broadcasting networks to be extended, virtually without limit, by operating additional transmitters carrying the same multiplexes on the same radiated frequency. The latter feature is known as the Single Frequency Network (SFN) [4].

The DAB+ standard is characterized by the following advantages and challenges [3, 7]:

Advantages:

- It is an open standard with no annual license fees to be paid by broadcasters.
- It can be implemented for a range of applications such as wide area or local delivery of audio and data services for mobile, portable and fixed reception.
- It can be delivered terrestrially.
- It is designed to be used across a wide spectrum range, from 30 to 300 MHz.
- It uses a wideband COFDM modulation system which provides a robust transmission which is multipath resilient and can provide high availability coverage.
- It can be implemented using on-channel repeaters in Single Frequency Networks (SFNs) or low power gap fillers and extenders. SFNs may also provide “network gain” giving improved service availability over single channel services.
- It can accommodate a varying number of audio services of differing quality with associated data. The audio quality can range from simple monospeech to high quality stereo.
- Data can also be delivered independently of the audio services, and standardized applications exist to enhance the audio service with visuals, program guides, and others.
- It uses mature technologies such as MPEG 1 Layer II (DAB) and HE AAC v2 (DAB+) audio coding systems and COFDM modulation, which are also used in the DVB-T video broadcasting standard. This has led to low cost single chip solutions for receivers.
- It has been standardized by international ITU recommendations, ETSI, CENELEC, IEC standards and national standards (e.g., Australian, British receiver standards).
- A large number of receivers are available for portable, PCs, mobile, in-car and in-house reception. Receiver prices continue to fall and hit rock bottom. DAB+ transmission has been shown to be an environmentally friendly technology when compared to FM.
- The standards include a number of features which can be used to implement Emergency Warning Systems and functionality including: automatic power on from standby through Emergency Warning signaling (Automatic switching of services to a specific Emergency Broadcast both within an ensemble or on a different ensemble, plus various multimedia support including text, images and applications).
- Well placed to be part of a Hybrid radio future, with terrestrial broadcast carrying audio and small data services alongside IP connectivity offering additional higher bandwidth services, personalization and backchannel interactivity.

Challenges:

- The MPEG 1 Layer II audio coding systems are now dated (compared with new systems) but they offer excellent robustness against channel errors due to unequal error protection (UEP). Most countries which adopted DAB are now converting to DAB+ to take advantage of the higher efficiency delivery – up to 2.5 times as many services can be delivered using DAB+ compared to DAB.
- While a wide range of low cost DAB receivers are already available, they are still generally seen as being too costly for general public acceptance in developing countries, particularly when compared to the very low cost AM and FM radios that many listeners currently use. As integration increases and single (RF + Baseband) chips become the norm, prices continue to fall and are expected to reach acceptable prices in those countries in the near future.
- The standard capacity of DAB+ using rate ½ FEC is 1.152 Mbps. Given a bit rate per service of 64 kbps, a single DAB+ ensemble can carry 18 services. In a conversion model, this may sometimes pose challenges for some radio broadcast markets, which are typically served by a mixture of narrowcasting, community, commercial and national services using AM and FM frequencies.
- The requirement for multiplexing will over time reduce the number of transmission sites and result in more consistent and cost effective coverage of digital radio services.

Although FM coverage still exceeds DAB/DAB+ coverage in most countries implementing any type of DAB+ service, a number of countries undergoing digital radio switchover are undergoing significant DAB+ network expansions, as of December 2019, WorldDAB provided the following worldwide population coverages (expressed in %):

Kuwait 100; Malta 100; Monaco 100; Vatican 100; Norway 99.7; Switzerland 99.5; Denmark 98; Germany 98; UK 97.3; Belgium 97; Netherlands 95; Gibraltar 90; South Korea 90; Czech Republic 85; Slovenia 85; Italy 84; Austria 77; Australia 65; Poland 56; Ireland 52; Tunisia 51; Sweden 41.8; Azerbaijan 30; France 25; Spain 20; Ukraine 7.07 [8, 10].

The digital world map of DAB/DAB+ network coverage provided by WorldDAB is presented in Figure 1 and that of three types of countries according to their development and implementtation: countries with regular services, countries with tests and/or regulations, and countries with interest.

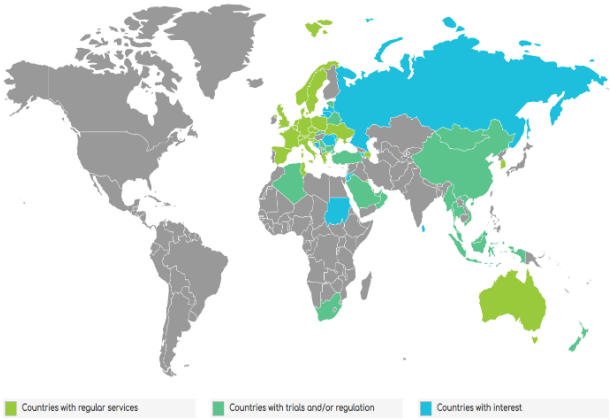


Fig. 1. Coverage of DAB/DAB+ network countries around the world [8]

There are also digital leaders, which are the countries at the forefront of digital radio according to most indicators, including wide coverage, expanded offering of new services, advanced legislation and regulation, including criteria and sometimes even switchover dates.

Countries with incomplete radio coverage are those where DAB+ has been launched nationally, with exclusive services (different from analogue broadcasting), receivers are on the market, promotional campaigns are underway and penetration is growing (at different rates). Digital Novices are those countries that have recently launched DAB+ services, with exclusive stations but limited coverage (specific cities or regions) and limited or lack of commitment from some key stakeholders. Let's see and wait for those countries, where regular digital radio services or trials are available, but there is almost no market due to lack of receivers but also in general, lack of commitment from the various stakeholders. Often this is also related to non-permanent launch of services.

The data included in the infographic shown in Table 1 for DAB/DAB+ is provided by WorldDAB members and partners including market research agencies, broadcasters, national digital radio bodies, national ministries, government bodies. WorldDAB collects the latest available DAB+ data on receiver sales, new car sales, population coverage, household penetration, road coverage, national DAB+ stations, digital radio reach, listening numbers, emerging markets. Updated and published twice a

year, the WorldDAB infographic includes important DAB+ data and figures for broadcasters, receivers and car manufacturers as well as listeners [6 – 9].

Digital Radio Standards more than 80% of digital stations use DAB+, while the DAB standard continues to phase out.

3. DAB+ PLANNING IN MACEDONIA (USE CASES)

For the commissioning of DAB+ equipment with a power of 500 W at JP Macedonian Broadcasting (JP MB) for the use of radio frequencies in the broadcasting service of digital radio (T-DAB), a temporary approval valid from 10.07.2019 to 09.07.2020 was received from AEC at the point Vodno - Skopje. The approval was issued for the use of radio frequencies for experimental purposes, for a limited area of coverage, for the purpose of introducing new technologies for a period not exceeding one year. During this period the DAB+ signal was broadcast without any problems.

T a b l e 1

DAB/DAB+ infographic data [6, 8]

Countries	Sales of cumulative DAB/DAB+ receiver 2008 - 2021	New cars with DAB/DAB+ %	DAB/DAB+ network coverage 2013 % 2021%	Road coverage DAB/DAB+ Km %	DAB/DAB+ household receiver penetration	Number of national FM DAB/DAB+ stations
United Kingdom	48.198 000	98%	94% 97.3%	46.000 km 87%	67%	8 56
Germany	21.600 000	94%	91% 98%	12.700 km 98%	27%	2 29
Italy	8.095 000	100%	65% 84%	6.500 km 95%	13%	21 50
Norway	7.000 000	100%	89% 99.7%	7.500 km 97%	73%	0 32
Australia	6.941 000	82%	63% 64%	/ 94%	51%	/ /
Switzerland	5.694 000	100%	99.5% 99,5%	1.450 km 99%	/	54 70
France	5.428 000	90%	8% 39%	/ /	13%	/ /
Netherlands	2.827 000	95%	/ >95%	4.800 km 95%	/	13 29
Belgium	1.887 000	98%	95% 97%	1.675 km 95%	21%	29 55
Denmark	1.547 000	94%	98% 99.9%	1.300 km 99%	36%	6 21

The 8 radio programs were broadcast on MRTV (4 program services used analog input (left and right audio channel), and 4 program services used digital AES/EBU input). The propagation was excellent because the DAB+ signal was heard without problems within a radius of about 50 km from the transmission point of RDO Vodno. In this way, it was possible for citizens who have appropriate receivers to familiarize themselves with the advantages of this technology. Then JP MB stopped broadcasting the DAB+ signal, because it did not receive a permission from AEC to continue broadcasting [6].

The JP MB launched an initiative to the Ministry of Information Society and Administration, for necessary legal changes (additions, adjustments and inclusion) of all stakeholders in the process for the introduction of DAB+ digital radio in the Republic of North Macedonia. Currently, there are 66 private FM radios and 4 radios from the national service (3 FM + 1 AM), of which 4 private and 4 from the national service cover the entire territory of the State, and the others are regional and local [6].

The DAB or DAB+, uses the VHF III frequency range of 174 to 240 MHz for transmission. The channel width is 7 MHz, which is divided into 4 DAB blocks, resulting in 4 DAB channels in one VHF channel (i.e. 12A, 12B, 12C and 12D). Each block is 7/4 MHz wide, i.e. 1.75 MHz, of which 1.536 MHz is used, and the rest is protection from adjacent channels. At the RRC-06 conference of North Macedonia has been assigned two allotment zones (Macedonia northeast and Macedonia southwest), shown on the division map of North Macedonia – Figure 2. At the same time, two multiplexes have been agreed for each allotment zone in the VHF area (174 – 240 MHz), presented in Figure 2. Channels 11 and 12 are intended for terrestrial sound broadcasting (T-DAB). Channels 11 and 12 intended for T-DAB are divided into blocks, where each channel contains 4 frequency blocks with a width of 1.75 MHz [6, 11].

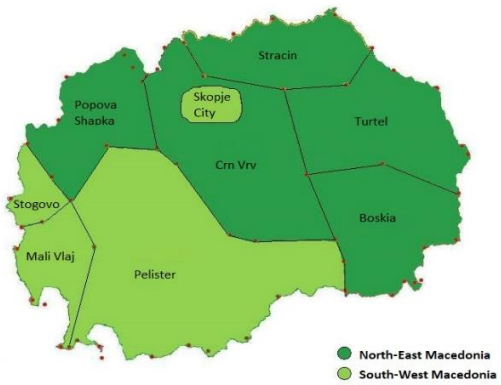
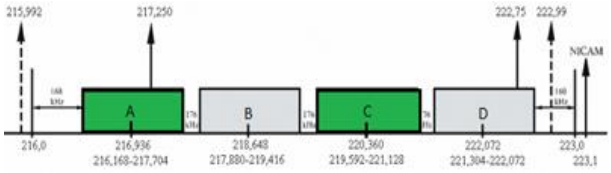
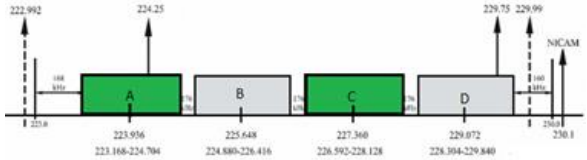


Fig. 2. SFN allotment zones in North Macedonia

Figure 3 shows the layout of DAB+ blocks for VHF channels 11 and 12 – on N. Macedonia. According to the frequency planning of the RRC-6 conference, i.e. AEC, Macedonia has been assigned – 11A and 12A (southwest and Skopje city), 11C and 12C (northeast) shown in Table 2 by blocks and frequencies [6, 11].



a) Schedule of DAB+ blocks in the 11th VHF channel



b) Schedule of DAB+ blocks in the 12th VHF channel

Fig. 3. Layout of DAB+ blocks in VHF channels 11 and 12

T a b l e 2

Frequency blocks for North Macedonia

Blocks	Range of blocks	Carrier	Allotment zones
11A	216.160 MHz – 217.696 MHz	216.936 MHz	south-west (SW) Skopje city
11C	219.584 MHz – 221.120 MHz	220.360 MHz	north-east (NE)
12A	223.168 MHz – 224.704 MHz	223.936 MHz	south-west (SW) Skopje city
12C	226.592 MHz – 228.128 MHz	227.360 MHz	north-east (NE)

The JP MB, taking into account the topology and population of the country – according to the analyses and propagation planning, to implement the DAB+ system by upgrading the infrastructure, mounting antenna systems and putting digital radio transmitters into operation at more than 30 broadcasting facilities throughout the territory of North Macedonia. With the planned antenna systems and powers of the DAB+ transmitting devices with which the DAB+ program will be broadcast on more than 30 broadcasting facilities in the network of JP MB in an 1+1 system, about 90% of the territory and roads of the Republic of North Macedonia will be covered at this stage. Further, with measurements and planning, it will be determined with how many transmitters (with which powers) to cover the rest of the territory of North Macedonia (from about 10%).

For the transmission of the DAB+ signal to all broadcasting facilities that are planned to broadcast it, the existing digital IP microwave link network would be used, which is currently available at around 85 locations of JP MB and which operates in a 2+0 system (2×155 Mbit/s). DVB-T multiplexes are currently being transmitted and broadcast through a digital IP microwave network to all those 85 locations of JP MB as well as the FM MPX signal using MPX/IP and IP/MPX converters.

However, for successful implementation of DAB+, it is necessary to design and perform new DAB+ antenna systems, but also larger infrastructure projects – in the construction part, steel structures and in the energy segment [6].

4. PILOT PROJECT FOR IMPLEMENTATION OF DAB+ IN NORTH MACEDONIA

The conceptual solution and conceptual project of the Antenna System for DAB+ (Kula Vodno), with general data given in Table 3, was jointly developed by the Submitters of the prepared paper and the companies Jampro Antennas from Sacramento (USA) and AlanDick Broadcast (Great Britain) with their specialized programs for that purpose. The proposed system is a vertically polarized DAB+ antenna system with 6 floors per vertical. Each element is arranged around the FM element with 2 DAB+ levels for one FM level. The DAB+ Dual Dipole is designed to give omni-directional with, a 4-way all-around configuration [6].

T a b l e 3

General data for the DAB+ antenna system

General Data	
Operating Frequencies	216 – 230MHz
Polarisation	Vertical
Horizontal Pattern	Omni-directional
Nominal Beam Tilt	5°
Null Fill	>12%
Antenna Aperture	8m
Number of Main Feeders	2
Antenna Input	1 5/8" EIA
Antenna Input Impedance	50 ohm
Maximum IP Power	3 x 2kW

Figure 4 shows the horizontal radiation characteristic, and Figure 5 shows the Block diagram of the DAB+ Antenna System with the arrangement of antennas, dividers, connecting cables and other elements.

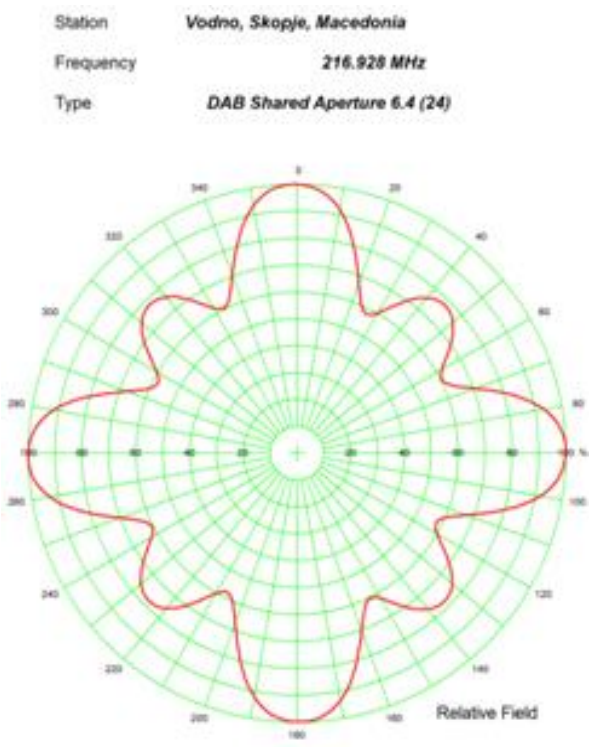


Fig. 4. Horizontal characteristic of radiation

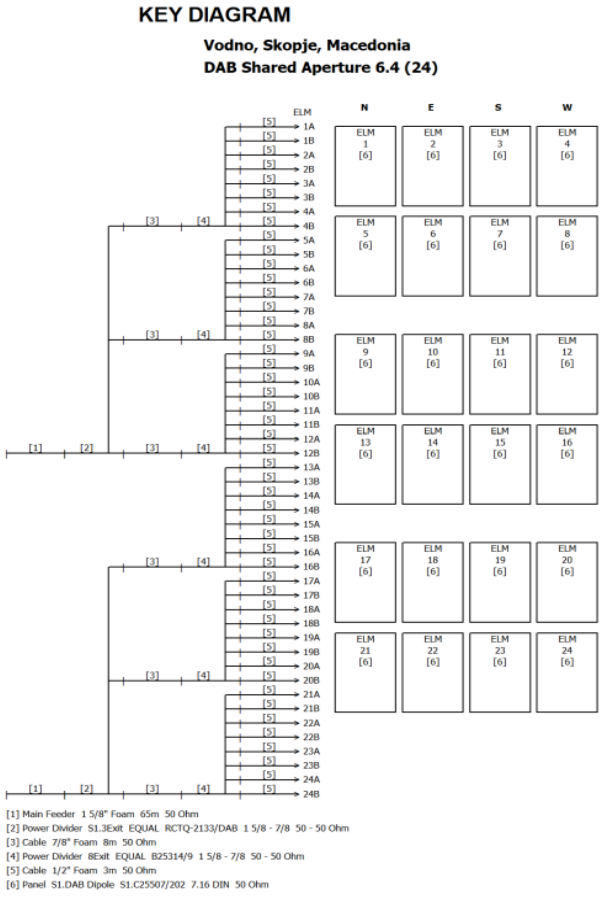


Fig. 5. Block diagram of the DAB+ Antenna System, Kula Vodno

Coverage predictions are made by software, taking into account the coverage parameters – shown in Table 4. Among other things, they take into account the use of land and buildings in the intended coverage areas and will be subject to some degree of variation depending on local conditions. The clutter databases used are Corine and Globcover. The database may not represent the exact land use at the time of the simulation.

T a b l e 4

DAB+ coverage parameters

Coverage Parameters	
Terrain Data:	SRTM 1 arcsecond 30m Resolution
Land Cover:	Corine and Globcover Clutter Databases
Model parameters:	
Surface refractivity (N-Units):	301
Ground Conductivity (S/m):	0.005
Ground Permittivity (Farads/m)	15
Climate:	Continental Temperate
Propagation Model	ITM (Irregular Terrain Model)
Probability	70% of situations 50% of time 50% of locations
Transmitting Site:	
Type:	Vertical Dipole
Mean Height	133.5m Shared FM Aperture
Transmitter Power	1kW
System Gain	9.3dB
Outdoor Receiver Parameters:	
Height:	10m / 1.5m
Gain	0dB
Recommended Minimum field strengths	54dBuV/m better than 95% 47dBuV/m better than 70%

SRTM1 30 m, resolution terrain data were used for this coverage prediction for 1 kW transmitter (Tx) power and the shown antenna system, for 1.5 m receiver height – Figure 6 [6]. The Figure 6 shows a coverage map in the region with a DAB+ signal field strength of 47 – 100 dBμV/m, shown in various colors. The coverage results were obtained with software solutions made by the mentioned companies, for the given parameters and antenna system for DAB+.

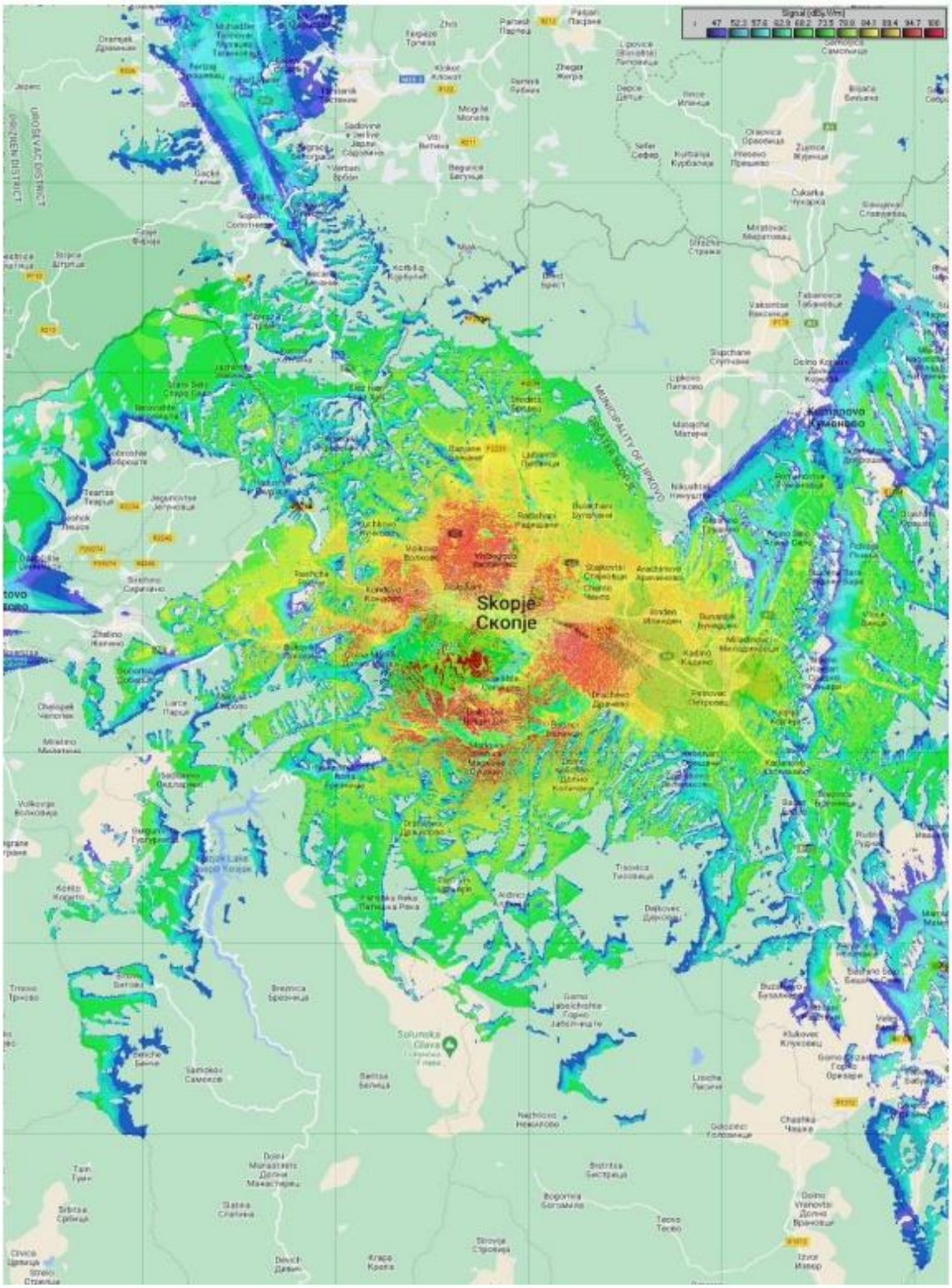


Fig. 6. 1kW TX coverage prediction (1.5 m receiver height)

5. CONCLUSION

This paper presents a platform or standard for broadcasting a system designed for digital audio broadcasting DAB+ radio services, with the delivery of high quality support of digital audio, video programs and data services for mobile, portable and fixed reception from terrestrial transmitters in the frequency bands (VHF III) in the Republic of North Macedonia. The DAB+ system is designed to provide spectrum techniques that are energy efficient in terrestrial transmission network planning, known as Single Frequency Network (SFN) and gap filling techniques. The DAB+ system meets the required criteria for sharing with other radio communication services.

We can conclude why Introduction of DAB+ digital radio in Macedonia:

• DAB+ is the best digital radio delivery system available.

• Proven technology.

• Efficient infrastructure.

• Deployed worldwide and expanding rapidly.

• Very flexible operation for broadcasters.

• Huge range of products for receivers.

• Great features including scrolling text, images, EPG and data services.

• Many new developments including interactivity.

The fact is that there are several technological, economic and environmental aspects that make DAB+ terrestrial digital radio advantageous to use. Many, including relevant research centers and experts, have analyzed the DAB+ and FM broadcasting systems. Starting with the consumption of electricity, how the supply of electricity and its consumption will be – become crucial questions in the years and decades ahead, as well as the increasing services offered by DAB+.

Concrete planning would be crucial for the future of broadcasting. In the countries of Western Europe, both FM analog radio and DAB+ digital radio with a network of transmitters work. This is supported by practical implementations that show that DAB+ is economically and environmentally cheaper and more positive than the existing FM system. Finally, the introduction of the digital broadcasting of audio signals through the DAB+ technology, which from the european studies and researches, was recommended as the most optimal solution for the transmission of audio signals in the countries that plan to start digitalization in this area, and thus for the Republic of North Macedonia.

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Original scientific paper

ANTICIPATED DEVELOPMENTS IN CLOUD SERVICES WITH A FOCUS ON THE INFRASTRUCTURE-AS-A-SERVICE (IaaS) MODEL

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A b s t r a c t: Delivery of fundamental processing, network and storage resources to users has never been easier through IaaS, a cloud computing model that utilizes the internet in order to provide users with scalable infrastructure on-demand. However, the technology is constantly being developed in order to provide better QoS to the end consumers, so efforts are being made to optimize every part of the IaaS model to make it function even better. This paper provides an explanation of cloud services, cloud service models with special attention to the IaaS model, as well as predicting future areas of research and development in the IaaS model, namely, eliminating interruptions in services, resource management, security, Serverless Computing, Edge Computing and containerization. Ways to implement ML/AI algorithms for resource allocation, containerization, security and predictive maintenance are also discussed. At the end of the paper, a review is given of the business aspects of IaaS.

Key words; cloud Services; cloud service models; IaaS; cloud resources; ML/AI

ОЧЕКУВАНИ РАЗВОЈНИ ТРЕНДОВИ КАЈ СЕРВИСИ ВО ОБЛАК СО ФОКУС НА МОДЕЛОТ IaaS

А п с т р а к т: Обезбедувањето на основни процесирачки, мрежни и мемориски средства никогаш не било полесно одошто преку користење на IaaS, модел на сервис во облак кој го користи интернетот за да им понуди на корисниците скалабилна инфраструктура во секое време. Сепак, технологијата константно се развива со цел да се постигне подобар квалитет на сервис за крајните потрошувачи, па се прават истражувања за оптимизацијата на секој дел од моделот IaaS да функционира уште подобро. Трудот во продолжение дава објаснување на сервисите во облак, моделите на сервиси во облак со посебно внимание врз моделот IaaS, како и предвидувања за идните истражувачки области и развојот на моделот IaaS, имено отстранувањето на прекините кај сервисите, менаџирањето со ресурсите, сигурноста, Serverless Computing, Edge Computing, како и контејнеризацијата. Исто така се дискутира за различните начини на имплементација на алгоритмите ML/AI кај алокацијата на ресурсите, контејнеризацијата, сигурноста и превентивното одржување на инфраструктурата. При крајот на трудот се дава осврт на бизнис-аспектите на IaaS.

Клучни зборови: сервиси во облак; модели на сервиси во облак; IaaS; ресурси во облак; ML/AI

1. INTRODUCTION

With the development of the internet and computer software technology, there is an increasing demand for cheap processing power and memory, leading to a growing interest in using cloud services. Essentially, the cloud represents a concept of virtualized resources that are offered as a service over the internet. These resources can take the form of hardware, memory, networks, and software. "Renting" these resources has proven to be a fast and easy way to deploy applications and store data. Many companies have embraced this model and are transferring their infrastructure to the cloud, which, in addition to being financially viable, offers many other benefits, such as quick and easy infrastructure setup and

configuration, and access to data from anywhere at any time. Despite all the advantages, the lesser control over infrastructure and security threats can be considered as disadvantages of this way of deploying infrastructure in the cloud. However, work is underway to improve these already known disadvantages through various research that is already yielding results in making the cloud more secure and accessible to users. The use of the cloud gives organizations of all types and sizes the opportunity to grow faster and modernize their infrastructure. It has completely transformed the way we work, communicate and collaborate, and is becoming increasingly necessary for staying competitive in today's digital world. The Infrastructure-as-a-Service model offers greater freedom in managing resources in the cloud compared to other cloud service models, and as such, is of interest for research and future improvements to the model.

2. FUNDAMENTALS OF CLOUD SERVICES

Cloud services provide access to computer resources such as applications, servers (physical or virtual), data storage memory, development tools, network capabilities, and more, which are located in data centers maintained by cloud service providers. This "rental" of resources brings several advantages, including lower costs resulting from the elimination of the need to purchase, install, configure, and manage one's own infrastructure, greater agility in the infrastructure setup process, and easier and more cost-effective infrastructure scaling based on demand. Data suggests that by 2025, half of the spending on application software, infrastructure software and system infrastructure will be transferred to the cloud, which accounted for 41% in 2022 [1].

In general, cloud services consist of three main parts: cloud service providers store data and applications on physical machines at locations known as data centers, users use these resources, and the internet connects these two parts over long distances. Although these parts are simple, the technology that connects them is very complex. There are several types of cloud computing, namely public cloud, private cloud, hybrid cloud, and multi-cloud.

The public cloud is managed by cloud service providers who make it available to the public. They own all the hardware, software, and infrastructure that make up the cloud. However, their customers own the data and applications that reside on the cloud.

Private clouds are most often maintained by organizations such as corporations and universities to enable exclusive use.

Hybrid clouds combine the previous two types and take the best of both. The private part of the cloud is used for sensitive functions, while the public part is used to withstand increased demand for services from customers. This provides flexibility and security without having to abandon existing infrastructure and security [2].

Multi-cloud represents the use of multiple clouds from multiple different service providers. This offers the advantage of using each separate cloud based on the specific need at the moment.

The cloud operates through virtualization. With virtualization of the cloud, users can use only the parts of the services or resources they need, without the need to own physical infrastructure where the use of resources is not adequately planned. This means that users can quickly change the amount of required resources, which reduces costs and increases the flexibility of the system by leaving room for future expansions or reductions of required resources. Virtualization offers the possibility for the cloud service provider to virtualize their servers, disks, or other physical hardware, which in return offers a large number of services such as infrastructure, software, and platforms. Infrastructure-as-a-service provides users with access to cloud servers, disk space, and network resources. This means that customers do not need to buy their own infrastructure, but rather use the virtualized infrastructure in the cloud. Improving the use of resources is very important to enable a larger number of instances for the consumer. Data storage in the cloud is done on remote servers. These servers are maintained by service providers who are responsible for managing, hosting and securing the data stored in their infrastructure. The service provider is responsible for making the data on their servers always available to users through a public or private cloud. Through this storage method, capital costs are eliminated and a model with operational costs is adopted. Users input data into servers via the internet, where it is stored on virtual machines on physical servers. To ensure availability, data is distributed across multiple virtual machines in data centers located all over the world. If there is a greater need for memory, more virtual machines are simply created to meet the demand. Access to the data by the user occurs via the internet. Storing data in the cloud is beneficial for users who need backups of their data, wish to archive old data, or require the use of

powerful tools for processing and analyzing data that are provided.

Service-oriented architecture is a development and delivery practice that provides software as a series of interoperable services. The services are designed to be individual units with minimal interaction between them, with each service providing a part of the functionality. These individual services are then orchestrated to build an application that utilizes these services. Web services are a crucial part of cloud services. They are the most common way to access services in the cloud [3]. Figure 1 shows the division of Cloud Computing.

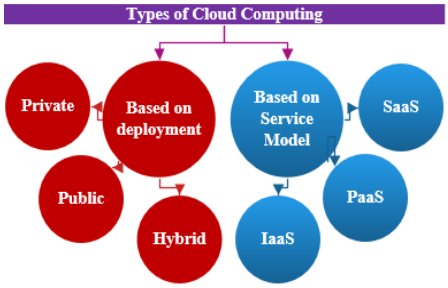

Fig. 1. Graphical representation of different types of Cloud Computing [4]

3. MODELS OF SERVICES IN THE CLOUD

The Software as a Service (SaaS) model provides software access through a subscription-based system, with the software located on external servers. Instead of each user having to install software on their own computer, they can access the program through the internet [5]. This model can be applied in several areas, including email services, product and service registration automation, document management, and more. Its advantages include enabling access from anywhere, lower costs, easy implementation, and easier upgrades, while its disadvantages include increased security threats associated with the way the model works, slower speeds, and less control. An example of SaaS is the Dropbox service, which is used as a cloud-based data storage service.

Platform as a Service (PaaS) is a cloud service platform that offers necessary software and hardware resources. This enables users to develop and manage their applications without maintaining the infrastructure required for software development. Essentially, PaaS provides an integrated solution to the user for application development, where code can be written, built, or managed without the need to install new versions of software and hardware, providing a complete development environment. This may include development frameworks, databases, and application servers [6]. A disadvantage is the limited control over the infrastructure. An example of PaaS is Red Hat OpenShift, which is a container management system that runs applications.

Infrastructure as a Service (IaaS) offers on-demand storage or virtualization in the cloud via the internet. Users are responsible for the operating system and any data and applications, but the service provider provides access to the network, servers, virtualization, and memory for data storage as needed. There is no need to maintain a proprietary data center, as the service provider handles all of that. Instead, the user gains access and control of the infrastructure through an API. IaaS offers flexibility in using only the necessary components and can be used as a fast way to set up and tear down development and testing environments. IaaS is commonly used in sales, as the number of sales during holiday periods typically increases, requiring a quick upgrade of infrastructure and the purchase of additional resources to handle the traffic during that period. The biggest drawbacks of this model are in the areas of security and trust, which can be overcome by selecting a good service provider that best meets the needs. Examples of IaaS include AWS, Microsoft Azure, and Google Cloud [7]. The difference between these cloud services can be seen in Table 1, by who is in charge of managing the resources.

T a b l e 1

Resources that are managed by either the user or a Service Provider (SP) depending on the cloud model

Model	IaaS	PaaS	SaaS
Applications	User	User	User
Data	User	User	SP
OS	User	SP	SP
Virtualization	SP	SP	SP
Servers	SP	SP	SP
Memory	SP	SP	SP
Network	SP	SP	SP

4. INFRASTRUCTURE-AS-A-SERVICE

IaaS, which stands for Infrastructure as a Service, is a model of cloud computing that provides access to virtualized resources via the internet. It is

one of three cloud service models, along with Platform as a Service (PaaS) and Software as a Service (SaaS). IaaS allows for quick scaling of required resources and helps users avoid the need for physical infrastructure. Each resource is offered as a separate component of the service. With this model, the service provider is responsible for the infrastructure, while the user installs and configures the software, including applications and operating systems. The main advantages of IaaS are:

• Users can utilize virtual resources without the need to purchase hardware.

• Infrastructure is scalable and can be easily changed based on the user's needs.

• It allows for virtualization of administrative tasks.

• The capital expense model is replaced with an operational expense model since the need to invest in hardware is eliminated.

Traditionally, the IaaS model has a problem with the pricing structure, which can be difficult to determine. Additionally, there is a lack of transparency from the service provider, making management and monitoring of systems challenging. Security is a significant issue as resources are accessed over the internet. Measures are being taken to improve the IaaS model to make it more attractive to users. Future trends indicate the implementation of various tools to improve resource management, control, security, and automation [7].

5. FUTURE TRENDS IN THE INFRASTRUCTURE-AS-A-SERVICE MODEL AND CLOUD SERVICES

The future of IaaS will likely depend on the growth and evolution of businesses that start to use the cloud instead of physical infrastructure. Users utilize IaaS to enable a wide range of functionalities, including software development, application testing, web hosting, and big data analysis. There are several obstacles and areas of development within the IaaS model that will define the future of cloud services.

a) *Elimination of service interruptions*

Interruptions in IaaS services are inevitable due to the nature of the model. The ultimate goal is to develop methods to minimize and even eliminate interruptions. These methods include quickly detecting the source of defects and resolving them. It is important to have some preparation in place in the systems and processes to enable a quick solution in case of a potential interruption. This problem represents one of the areas in which the IaaS model will develop in the future. There are several ways to build tolerance for interruptions in the infrastructure as a service, such as developing monitoring of the behavior and security of the components that manage access to the cloud infrastructure. Another way is to enable backup of data at multiple remote locations so that in case of a work interruption at one location, functionality can be provided by the remaining locations. This solution, however, represents an expensive alternative as it requires a significant investment in support infrastructure that would not be used every day.

b) *Resource menagement*

As the demand for IaaS increases, so will the demand for resources, making it of great importance for service providers to implement appropriate resource management models to achieve maximum profit. This need will drive interest in developing new, more efficient resource management models. The resources offered by the IaaS model should be allocated according to current needs, while ensuring good quality of service for end users. These resources are not unlimited, so it is important to distribute them efficiently. To effectively distribute resources, it is necessary to overcome obstacles such as resource provisioning, resource mapping, resource distribution, and resource adaptation.

1. *IaaS provisioning*

Provisioning of resources for users or applications through load balancers, mechanisms for enabling high availability, and the like is crucial for improving service quality in IaaS. In the future, there will be developments in the elasticity of applications hosted in the cloud in order to obtain an increased amount of resources and a reduced cost for their use, while keeping the parameters that the user requests in mind. Of interest also is progress in developing models for predicting resource needs in hosted applications in order to minimize the impact of increased resource usage with the least possible performance drop. Designing an algorithm for resource provisioning that converges to optimal processor allocation based on the rate of incoming data and processor power needs is yet another part of IaaS provisioning that is in development.

2. *Resource allocation*

When it comes to resource allocation, the optimal solution is achieved when the allocation made

to satisfy needs has the minimum possible cost for the infrastructure and in the shortest possible time period. Different resources are required for different needs of IaaS, so finding these resources and allocating them is of great importance. Allocation is performed according to predefined policies. Creating a resource allocation scheme that spans multiple clusters, creating mechanisms to control the cost-to-reconfiguration ratio and maximize cloud utilization, as well as relocating virtual machines while minimizing the system cooling consumption are just some of the areas of research when it comes to optimizing resource allocation.

3. *Resource mapping*

Resource mapping is one of the processes that build the system that enables the identification of existing resources and their application for specific needs. The problem here is achieving maximum utilization of the cloud in IaaS by calculating the capacity of the application's needs, in order to establish and maintain a minimal processing infrastructure. This is achieved through the use of a cognitive architecture that automatically creates a machine behavior model using previously collected data. Mapping logical nodes to physical nodes, finding physical resource allocation that corresponds to the needs of the logical network, developing models that predict how applications will perform based on various parameters such as processor, memory, network, and disk usage, as well as mapping application needs to cloud offerings to find a cloud service that best suits the specific application, are several areas that will be developed in the future.

4. *Resource adaptation*

Resource adaptation in the cloud is a crucial advantage, as it transitions to a model of operational costs and eliminates the need to purchase one's own infrastructure and hire personnel to maintain it, instead moving to a model where these resources are "rented". Such resources can easily be adjusted to everyday needs, avoiding over-provisioning. The most important part of resource adaptation is to maintain service quality and minimize costs, and progress in these areas is expected in the future [8].

c) *Security*

As the rate of migration to the cloud increases in the future, the motivation for cybercriminals to target cloud environments will also increase. Although cloud environments are protected by various security measures, they are still susceptible to security threats if not properly configured. In the future, attention will be focused on improving security, which will lead to the emergence of new security plans. Therefore, it is necessary to understand the development and security needs in the cloud to ensure a secure environment. In 2022, it was reported that 15 billion data records were stolen from 1.1 million compromised user profiles of 17 well-known companies, only through the method of "Credential Stuffing" [9].

1. *Cybersecurity mesh – CSMA*

The architecture of the network for cybersecurity is designed in a way that enables a scalable approach to extending security controls, even in distributed environments. It is built on a strategy of integrating distributed security tools through data centralization and control partitioning to achieve more effective collaboration among the tools. The cybersecurity network allows the tools to work together across multiple levels, such as consolidated policy management, security intelligence, and distributed identity frameworks that support identity and access management (IAM) frameworks. The result is improved detection capabilities, consistent policies, efficient responses, and adaptive access control. With this approach, a way is created for individual security services to communicate and integrate with each other, creating a dynamic security environment throughout the network. This protects all endpoints, rather than relying on a single technology to protect all assets. The use of this technology in IT creates the possibility of implementing a modular system that can be applied to multiple architectures simultaneously, centralizing security policy management. The advantage of this approach lies in its ease of implementation, practicality, and agility, making it a solution for the immediate needs brought about by digitalization, such as vulnerability to attacks, the cost of such attacks, and the growing migration to cloud-based systems. CSMA is also considered one of the building blocks of the Zero-Trust architecture.

There are four basic levels of CSMA:

• Security analysis and intelligence that enable the collection and analysis of large amounts of data from multiple locations at a single location, from which appropriate measures are taken.

• Security intelligence and distributed identity frameworks that support identity and access management frameworks, enabling adaptive access, decentralized identity management, and directing services.

• Consolidated policies that provide a central policy for all individual security tools, simplifying the detection of fraudulent attempts and problems.

• Consolidated control panels enable a more composite way of tracking security information obtained from systems, which helps with quick reactions and taking appropriate measures.

2. *Zero-trust architecture*

The Zero-Trust approach is a way to increase security through greater control of authentication, authorization, and security posture validation before allowing access to applications and data. This approach is modern and will be increasingly implemented in the future with the possibility of remote work, as it provides a way to give employees secure access to the applications and data they need from the work environment. By using Zero-Trust, attention is turned to security issues that arise as a result of hybrid cloud environments and hacker attacks. Implementation is done through a combination of advanced technologies such as multi-factor authentication, identity protection, user endpoint security, and system security maintenance. Traditional security approaches rely on end-users within an organization, which can lead to the risk of hacker attacks through the takeover of the credentials these end-users use to log into the system or the risk of internal attacks. The Zero-Trust architecture requires continuous monitoring and validation that end-users and their devices possess the appropriate privileges assigned to them. This approach is used in hybrid cloud systems, systems composed of multiple clouds, or multiple identities. It is used for SaaS applications and outdated systems. Zero-Trust adheres to the following basic principles:

• Continuous verification of all access attempts, protecting all existing resources.

• Minimization of potential damage from a possible attack by isolating users, giving them different privileges, or segregating the network to reduce the surface area that can be compromised by a security attack.

• Automating the processing of security data to accelerate the response process in the event of a security attack [10].

3. *Hybrid clouds and multi-cloud environments*

Full migration to a single cloud can be risky, so the model of deploying applications or data in different locations or clouds is increasingly chosen to ensure avoidance of complete losses. Hybrid cloud is a type of cloud service that combines private clouds (infrastructure physically located at the user's site) and public cloud. Hybrid clouds allow data and applications to be moved between the two environments. This model is used to comply with regulatory requirements, address latency issues, or maximize investments in proprietary infrastructure. Multi-cloud environments are a model in which cloud services from more than one cloud service provider are used in a heterogeneous environment. This allows for greater flexibility and reduces risk. Cloud services are chosen based on needs, so different service providers can offer services that are ideal for different applications. The use of this approach is growing and is expected to be one of the ways to ensure the existence of data and the operation of cloud-based applications [11].

4. *Security measures in the cloud*

The security approaches that are applied to the infrastructure owned by the user are not always sufficient for the cloud infrastructure, so special security measures are developed for the cloud. These measures enable the entire process of cloud applications, from infrastructure planning to deployment and maintenance, to be secured. One such security tool is Kube-bench, which checks whether the Kubernetes container orchestration tool is implemented according to best security practices. Some of the important measures include:

• Encryption of data, meaning that data is encrypted or ciphered during transmission and storage. There are various algorithms for implementing encryption, and the choice depends on the user's technical knowledge to prevent data loss.

• Network security, which involves dividing the network into multiple network segments, preventing external attacks, and allowing or denying access.

• Security checks through the use of security tools that serve to secure the infrastructure.

• Data backup in the event of unexpected loss due to natural disasters, which is often implemented by setting up backup servers at remote locations [12].

5. *DevSecOps*

DevSecOps is an approach that combines application development, security, operations, and IaaS in an automated CI/CD pipeline. The main goal

is to automate, monitor, and implement security in all phases of software development. Implementing security at every level of software development allows for cost reduction, reduced risk of security issues, and faster software deployment. The benefits of establishing a DevSecOps culture include increased quality and security of software, increased communication and collaboration between teams, faster resolution of security incidents, stronger security protocols, increased use of automation, particularly in the QA process, as well as earlier detection and correction of vulnerabilities in the code.

Practices used in implementing DevSecOps methods include:

• Implementation of automation to secure the CI/CD environment by adding security controls and testing throughout the entire development process.

• Dealing with open source software commonly used in application development. Implementation of automated processes that ensure code security is critical for this type of software tool.

• Adding security systems that provide information about the nature of defects, their severity, and the measures that need to be taken. This way, security risks can be resolved before they are deployed in production environments [13].

d) *Serverless computing*

This model allows service consumers to automatically allocate resources based on received user requests without the need for provisioning or server management by the user. In the context of IaaS, this model can be implemented through services such as AWS Lambda, Azure Functions, or Cloud Functions. These services enable the user to deploy their application and select a suitable function to process the application. The cloud service provider owns all the necessary infrastructure that automatically scales based on the user's needs, charging only for the resources used. The reduced need for infrastructure management, cost optimization through charging only for dynamically changing resources according to demand, scalability, and increased availability resulting from handling interruptions in functioning, motivate the development of serverless cloud services implementation [14].

e) *Edge computing*

By bringing processor and memory resources closer to data sources and users, latency and bandwidth requirements of traditional centralized implementations are reduced. Data is processed and analyzed at the edges of the network, where data is created or collected, rather than being sent to a centralized cloud for processing. This approach to resource management in IaaS environments is achieved by extending infrastructure to the network edges. This is done by creating virtual machines or containers on end devices such as routers, switches, and the like, which can "carry" applications and process data locally. This provides greater flexibility and scalability, and allows for filtering of data sent to the cloud [15].

f) *Containerization*

Containers represent a method of packaging and deploying applications in an easy and portable way, where each container contains all the necessary components to ensure the function of the application that resides on it. Containers can be applied in IaaS environments by deploying them on the virtual machines offered by the service provider. In this way, the advantages of containerization such as isolation, scalability, and portability are combined with the benefits offered by the IaaS model. In such an implementation, the user will be responsible for deploying the required container images and orchestrating the containers themselves. Containers in IaaS can simplify the deployment and management of applications by offering a consistent and portable environment. They can also offer scalability and optimal resource utilization by enabling multiple containers to run on a single virtual machine, as well as easy deployment of new versions of applications based on current needs. When it comes to container orchestration, platforms like Kubernetes or Docker Swarm can be used to further simplify the work and management of the containers on which applications are deployed.

6. ML/AI IN CLOUD SERVICES

AI and ML can be used to improve the function of the IaaS model by optimizing resource allocation and managing IaaS environments through analyzing past environmental behavior. They can provide assumptions about the future behavior of the system and its needs and automatically allocate resources to meet these needs. This improves performance, reduces costs, and improves overall resource utilization.

The use of the Markov Decision Process (MDP) and Bayesian learning helps for the optimization of dynamic resource allocation when implemented in cloud computing services. MDP helps in the alloca-

tion of resources for network function virtualization, while Bayesian learning aids in predicting the future utilization of resources by analyzing existing patterns. These models proved better than the traditional way of resource allocation in terms of cost [16]. The cost optimization of resource usage is a very important parameter in resource allocation. ML can be used in order to cut unnecessary costs from bad resource allocation strategies by identifying resources that are consistently underutilized and scaling them down or completely turning them off. In [17], a hierarchical framework is proposed that tends to solve both resource allocation and power management problems. It helps to perform the local power management of servers in an online and distributed way.

In terms of containerization and the different ways of container scheduling, the Kubernetes Container Scheduling Technique (KCSS) proves to improve the scheduling efficiency of containers. This is achieved by selecting the most suitable nodes together with a combination of dynamic needs from the customer and the status of the cloud computing for each requested container [18].

AI and ML also enhance security in IaaS environments by identifying potential threats and vulnerabilities. They learn from system data such as network traffic and analyze anomalies that could indicate security threats. This is achieved by finding patterns of behavior that can lead to security threats. ML algorithms can be trained to use these patterns in recognizing potential threats in network traffic like the different types of attacks, for example the Distributed Denial of Service (DDoS) attacks, phishing attempts and SQL injection attacks. Other implementations of AI and ML in IaaS can be found in access control and authentication mechanisms and automation of incident response in IaaS environments. Many models can be created for improving IaaS environment security in many different ways. One way is through supervised Artificial Neural Networks (ANNs), like the Levenberg-Marquardt (LMBP) algorithms, which besides improving security, can help in resource allocation, workload scheduling and energy optimization by minimizing the error between the predicted output and the actual output of the algorithm [19].

In this way, these security threats can be located and prevented before they occur, but it is important to mention that these algorithms can also become a target for attacks themselves, so it is best practice to combine them with other security measures. Also, like every other ML/AI algorithm, they rely on the accuracy of the models and a bad model can give incorrect data and generate false alarms, so it is important to use accurate models.

Predictive maintenance of infrastructure in IaaS through the use of ML and AL algorithms can help predict hardware component failures or other parts of the infrastructure. This reduces the time needed to service the infrastructure. The use of these tools can improve scalability by automating it, as well as automation in setting up loads, while minimizing downtime and making sure the infrastructure is working as intended. The Random Forest algorithm, as well as the Support Vector Machine (SVM) algorithm, for example, can be trained on data in order to predict infrastructure failures based on classifications of events.

7. BUSSINESS ASPECTS IN IaaS

IaaS opens up new horizons for businesses by providing the ability to transfer their entire infrastructure to the cloud. This migration offers complete elimination of capital expenditures (CapEx) and transition to an operational expenditure (OpEx) model. Additionally, the need for infrastructure maintenance, which would be maintained by the service provider in the cloud, is reduced. This way, attention is directed towards essential parts of the business that generate profit, such as product development, without worrying about the infrastructure on which the development occurs. This infrastructure setup, which is based on subscription to cloud service providers, can bring cost reduction, which can be shared in a short-term cost reduction and a long-term cost reduction. Both types are equally important for increasing the company's profit and reducing investment risk. In addition to these cost reductions, there is also an increase in business productivity by enabling greater efficiency of infrastructure usage by the user. This increases the value of the company itself. Projected increase of total revenue in the cloud is shown in Table 2.

Table 2

Projected increase of total revenue in the cloud [20]

Year	2022	2023	2024	2025
Total revenue ($B)	544	655	779	917

a) *Short-term cost reductions*

Choosing the IaaS model as a way to set up infrastructure in companies with existing infrastructure brings a reduction in short-term costs by utilizing and paying only for the necessary resources without owning too many unused resources. For new companies, it brings a benefit in reducing initial investments. By reducing initial investments, these companies can allocate part of the budget intended for purchasing and setting up infrastructure to other areas of the business, making the initial state of the company much better. Also, by outsourcing the maintenance of the infrastructure to someone else, the need for personnel in the company is reduced, thereby reducing the required initial budget for salaries.

b) *Long-term cost reductions*

Owning your own infrastructure is not a one-time investment, it has a lifecycle and over time new investments will be needed for repairs and upgrades, something that the user does not need to worry about when using IaaS, through which they can get additional resources with a few clicks without having to worry about the lifespan of the infrastructure. In addition, owning your own infrastructure also requires regular installations of new technologies and other improvements. When this happens, the infrastructure functions partially or does not function at all, reducing the productivity of the company. The space occupied by the infrastructure, i.e. the data centers, can be used for other purposes, or in the case of renting the space, the need to pay rent can be eliminated. The reduced need for personnel to maintain the equipment also has long-term benefits in reducing the costs of the company. By eliminating capital costs and moving to an operating cost model, the user is able to adjust resources according to current needs. As a result, unnecessary costs for unused resources are avoided, as only the resources used are charged for.

8. CONCLUSION

Infrastructure as a service (IaaS) is a cloud model that provides virtualized resources such as servers, memory, and network infrastructure over the internet. IaaS allows users to access these resources on-demand without the need to invest in or maintain their own infrastructure. Users can choose this model for web hosting, data storage, backup, or application development. Some benefits offered through the use of IaaS are scalability, flexibility, and cost savings. The model provides scaling of the amount of resources used as needed, where the user only pays for the resources used. However, there are also areas where improvements can be made, such as implementing tools to improve the model's function.

Eliminating interruptions in services is of particular importance because each interruption represents a loss of money for the service provider and a loss of resource usage opportunity for the user. Optimizing resource management enables resources to be allocated to more users, thereby increasing profits. Through the use of artificial intelligence and machine learning, containerization, serverless computing, and edge computing in the IaaS model, improvements in the model's operation, i.e. its automation and optimization, are offered. Security is the most critical element in enabling the normal function of the model and is one of the main subjects of research and progress in recent times. Since the cloud operates over the internet, the risk of security attacks is increased, so new and improved security measures are developed daily to make the cloud impervious to hacking attacks.

Infrastructure as a service is a powerful tool that enables users to access and use virtualized resources in a flexible and relatively inexpensive way, making it a popular choice for use, and the popularity itself brings with it future innovations.

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Articles received by the Editorial Board are sent to two referees (one in the case of professional papers). The suggestions of the referees and Editorial Board are sent to the author(s) for further action. The corrected text should be returned to the Editorial Board as soon as possible but in not more than 30 days.

PREPARATION OF MANUSCRIPT

The papers should be written in the shortest possible way and without unnecessary repetition.

The original scientific papers, short communications and reviews should be written in English, while the professional papers may also be submitted in Macedonian.

Only SI (Système Internationale d'Unites) quantities and units are to be used.

Double subscripts and superscripts should be avoided whenever possible. Thus it is better to write $\nu_3(PO_4)$ than $\nu_{3_{PO_4}}$ or exp(–E/RT) than $e^{-E/RT}$. Strokes (/) should not be used instead of parentheses.

When a large number of compound have been analyzed, the results should be given in tabular form.

Manuscript should containt: title, author(s) full-name(s), surname(s), address(es) and e-mail of the corresponding author, short abstract, key words, introduction, experimental or theoretical back-ground, results and discussion, acknowledgment (if desired) and references.

The **title** should correspond to the contents of the manuscript. It should be brief and informative and include the majority of the key words.

Each paper should contain an **abstract** that should not exceed 150 words and **3–5 key words**. The abstract should include the purpose of the research, the most important results and conclusions.

The **title**, **abstract** and **key words** should be translated in Macedonian language. The ones written by foreign authors will be translate by the Editorial Board.

In the **introduction** only the most important previous results related to the problem in hand should be briefly reviewed and the aim and importance of the research should be stated.

The **experimental** section should be written as a separate section and should contain a description of the materials used and methods employed – in form which makes the results reproducible, but without detailed description of already known methods.

Manuscripts that are related to **theoretical studies**, instead of experimental material, should contain a sub-heading and the **theoretical background** where the necessary details for verifying the results obtained should be stated.

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Figures (photographs, diagrams and sketches) and **mathematical formulae** should be inserted in the correct place in the manuscript, being horizontally reduced to 8 or 16 cm. The size of the symbols for the physical quantities and units as well as the size of the numbers and letters used in the reduced figures should be comparable with the size of the letters in the main text of the paper. Diagrams and structural formulae should be drawn in such a way (e.g. black Indian ink on white or tracing paper) as to permit high quality reproduction. The use of photographs should be avoided. The tables and the figures should be numbered in Arabic numerals (e.g. Table 1, Figure 1). Tables and figures should be self-contained, i.e. should have captions making them legible without resort to the main text. The presentation of the same results in the form of tables and figures (diagrams) is not permitted.

Figures and tables must be centred in the column. Large figures and tables may span across both columns (Figure 1).

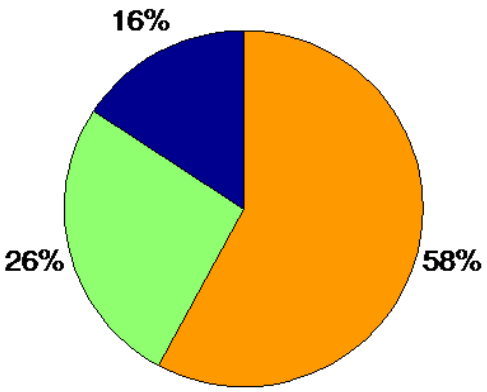

Fig. 1. Example of a graph and a single-line caption (collour)

Graphics may be full colour. Please use only colours which contrast well both on screen and on a black-and-white hardcopy because the Journal is published in black-and-white, as shown in Figure 2. The colour version is only for the electronic version of the Journal.

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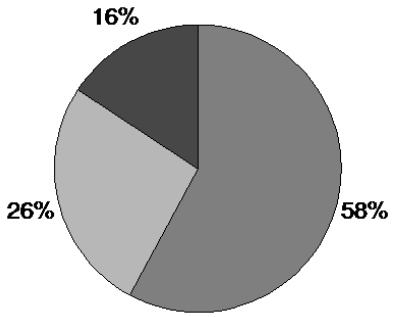

Fig. 2. Example of a graph and a single-line caption (black-and-white)

Fig. 3. Example of an image as it will appear at the electronic version of the Journal and a multi-line caption

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REFERENCES

[1] Surname, N(ame).; Surname, N(ame). (Year): *Name of the Book*, Publisher.

[2] Surname, N(ame).: Surname, N(ame). (Year): *Name of the Book*, Name of the Series. Publisher, **vol.** XXX.

[3] Surname, N(ame).; Surname N(ame). (Year): Title of the article, *Name of the Journal*, **Vol. XX,** No. XX, pp. XXX–XXX.

[4] Surname, N(ame).; Surname N(ame). (Year): Title of the article, *Proceedings of the Conference (Name)*, **Vol. XX,** pp. XXX–XXX.

[5] Surname, N(ame).; Surname N(ame). (Date dd. mm. yyyy): *Name of the Patent*, Institution that issued the patent & Number of the patent.

[6] N.N. (Year): *The XXX web site*, web address.

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[11] Surname, N(ame)., Surname, N(ame). (Year): *Title of the Report*, organization that issued the report, Number of the report.

[12] Institution that issued the standard, *Name of the Standard*, & Number of the standard (Year).