Planning Telecommunications Infrastructure in Kosovo through Geographic Information Systems (GIS)

Kastriot Dermaku, Liridon Hoti, Ilir Gashi, Selami Klaiqi

Abstract: *Nowadays, we know how important it is for a country to have a good telecom infrastructure, including Kosovo. The purpose of this paper is to plan the telecommunications infrastructure based on the geographic information provided by GIS. By using these systems, we can draw analyses and conclusions on the possibility of planning the extension of this infrastructure in the future, consequently conveying ideas to different sectors of development or for using telecommunications infrastructure. The data by which the scenarios of this study have been drafted, are real and generated in Prishtina. They are employed to illustrate the use and techniques of GIS.*
Keywords: *Geo-referencing; Geo-database; GIS; GPS; RAEPC; ITU; ESRI; TCP/IP.*

EXPLANATION OF THE GIS PLATFORM IN THE REGULATORY AUTHORITY OF ELECTRONIC AND POSTAL COMMUNICATIONS IN KOSOVO

1. Application of GIS for Electronic Communications

The application of GIS in planning telecommunications infrastructure serves to carry out service planning concerning electronic communications.

The application can work within the local network and it can be accessed even from outside the network. This allows telecommunication operators to access only their data and modify them.

1.2. Application Contents

The application contains data for public networks of electronic communications as shown in Figure 1 [11].

(1) Wireless network and mobile telephony / radio transmission;
(2) Cable route;
(3) Landline telephony network;
(4) Underground network.

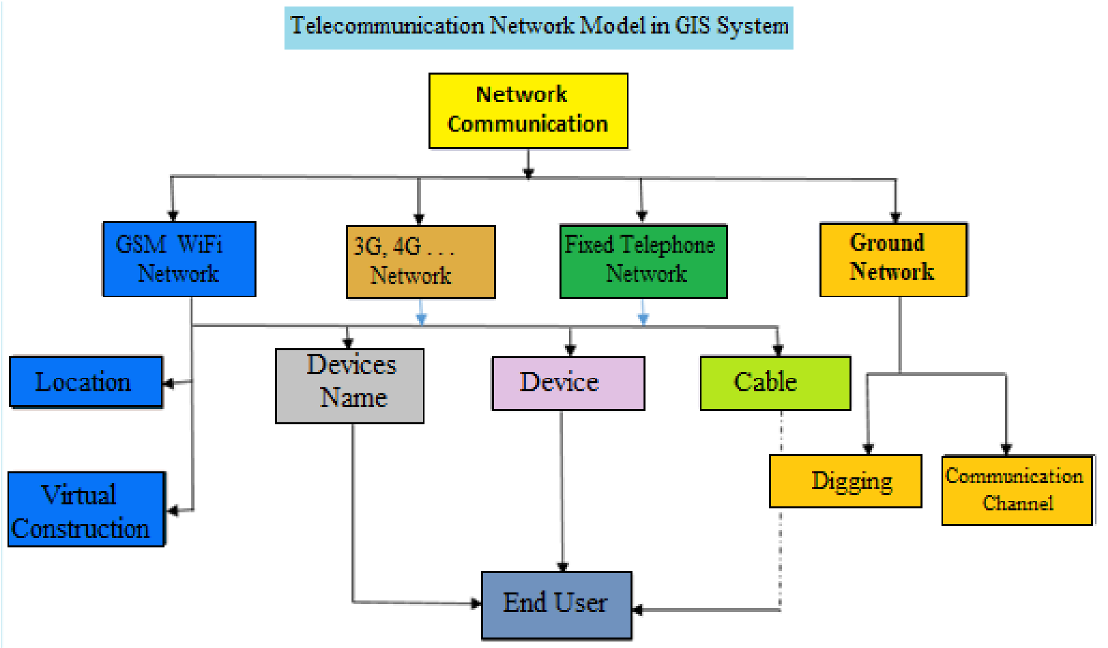


Figure 1. Telecommunication Network Model in GIS Systems [11]

For the purpose of visualizing, analyzing and predicting the effects of telecommunications infrastructure, and the planning thereof respectively, data have been organized into GIS system scenarios and broken down by the nature of the type they belong to or the area of application.

1.3. Introduction to the GIS System

The RAEPC platform has been designed to provide simultaneous access to operators, realized through a separate link, and to RAEPC, realized directly from the desktop platform as shown in Figure 2.

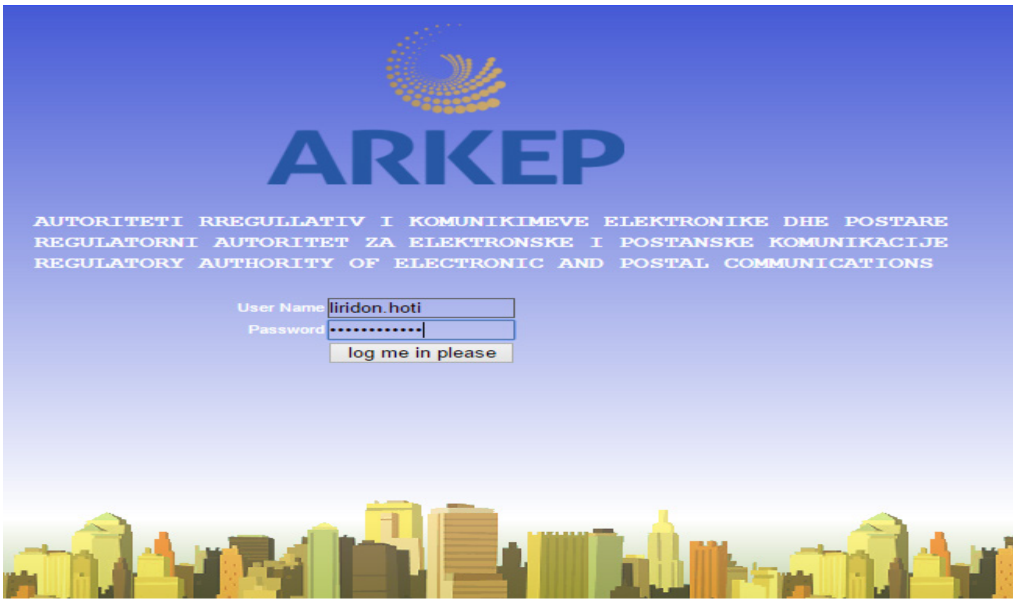


Figure 2. Access to the GIS System Application [11]

The GIS system is considered an application working with geographical data.

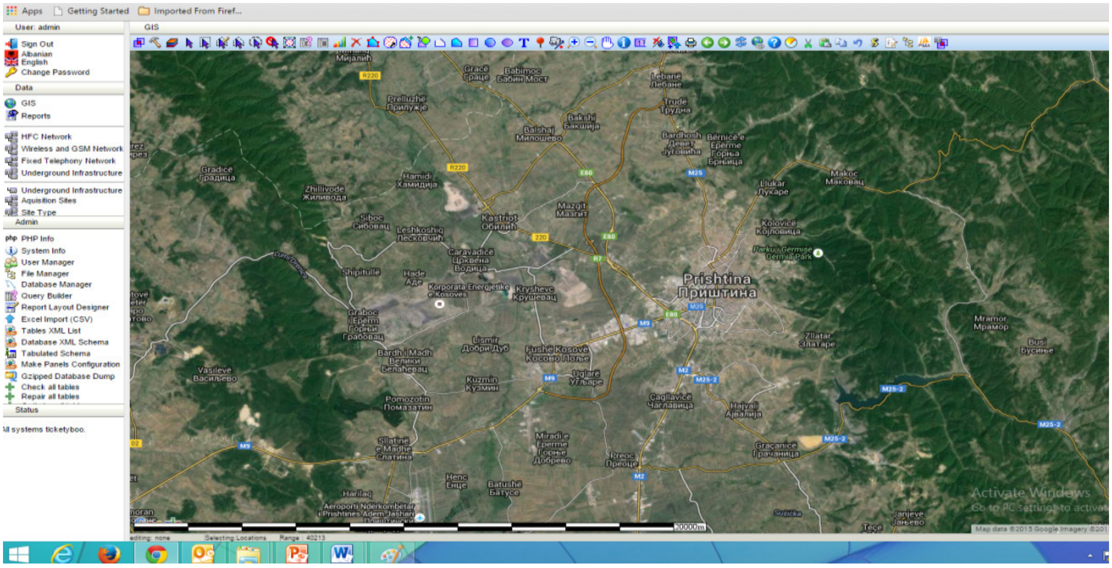


Figure 3. GIS System Platform [11]

Like any system, GIS is a set of structures interfaced in a way that allows it to perform multiple tasks. These structures include computer hardware and software, the location where they are deployed, personnel who use the system at a variety of levels and capacities, as well as data and information on which the system operates.

2. GIS Systems in Kosovo

As GIS systems have not been used in Kosovo before, the planning of the country’s telecommunications infrastructure caused a number of significant problems:

- We could not test and manipulate the variables quickly and appropriately;
- Testing of telecommunication models was costly;
- We have not been able to predict the consequences of different activities and thus choose the “best option”;
- We could not request and retrieve data from attributes based on specified criteria and present the results in space where we need them.

Telecommunications infrastructure planning involves the analysis of data including one or more combinations, such as:

- Measurement of spatial features by devices (e.g. antenna radiant power) and the impact of other devices (e.g. interferences) within a layer of information or between different layers;
- Compilation of questionnaires, comparison and calculation of attributes. This is the search action for the required data in the database;
- Application of spatial functions in existing data layers and creation of new layers with the results of the functions;
- Combining the geometries and attributes of one or more layers of information by means of the corresponding functions;
- Using a spatial layer to separate geometries or attributes using the reciprocal position with a given layer [1].

With the implementation of GIS in Kosovo, “questionnaires” have been integrated in order to reach the necessary information faster, and to be able to plan telecommunications infrastructure on the basis thereof. The structure of telecommunication networks often limits the number of interconnections in networks, but by planning through the virtual system in GIS, a reflection of the connection of an optical cable with the end user can be achieved.

The passage of cables in any area can also be observed. Difficulties with the technical description of the infrastructure, its extension and the obstacles during the expansion of networks have led to areas where the real-time focus of data transfer is greater. Planning telecommunications infrastructure through GIS is a precondition for increasing network reliability.

2.1. The Role of GIS in Telecommunications

As a software tool, GIS systems enable telecommunication professionals to integrate maps and information, and make decisions regarding network infrastructure planning and maintenance, mobile telephony coverage management, cable extension management, Internet services, etc. [20, 5].

In order to make an accurate representation of any infrastructure, the program should allow us to deal with problems, such as modifying, presenting and processing geographically referenced information [2]. The reflection of the telecommunications infrastructure through GIS enables us to consolidate the knowledge in solving problems of electronic communication infrastructure through the programming platform. With the use of GIS, we manage to do virtual planning of communication techniques in telecommunications and plan the location of services in telecommunications. GIS for telecommunications infrastructure planning means the structure and operation of virtual design [14].

Through the GIS system in Kosovo, we have managed to plan the telecommunications infrastructure by enabling a reflection on the information in a certain area. The largest layer is integrated planning that contains information about the terrain topology in which the network operates. The integrated plan includes layers that describe telecommunication systems, etc. The telecommunications infrastructure planning layer contains all the important information related to the network description and infrastructure monitoring based on specific transmission media [10].

2.2. Use of GIS System Technology in Kosovo

The application of system technology in the field of telecommunications has an indisputable impact and advantage in all processes, such as decision-making, information control, increasing effectiveness between operators, enhancing the quality of telecommunication services or increasing control in telecommunications.

Familiarity with methodologies through GIS system technologies enables us to improve processes in every aspect in the field of electronic communications. The possibility of using the GIS system in Kosovo offers many functionalities. They can be extended through installing additional tools that allow us to make various plans in the field of telecommunications.

3. Cell Planning Module

Cellular coverage, particularly wireless signal propagation, can be planned to increase area coverage as much as possible by making the most efficient use of the frequency band. This will enable predictive accuracy, reduce interference and optimize the application of wireless network systems. Planning is closely linked to geographic information and that is why we rely on the GIS platform.

Table 1. Cell Planning Scheme

Cell planning module	**Planning module through the GIS system**
	Prediction module
	Database module
	Data analysis module

By using GIS, we can therefore predict the effects of losses during wave propagation from base stations. Visual results facilitate us in taking decisions on cellular signal coverage planning. The planning module through GIS is the module for predicting different scenarios. It allows us to achieve the most optimal results [5, 6, 7].

Figure 4. Cellular Coverage in Prishtina [11]

As it can be seen in Figure 4, the GIS platform allows us to identify potential points for achieving maximum coverage.

The purpose of using data in relation to these points from the GIS planning system is to improve the actions of each operator, reduce costs, facilitate periodic analyses and ensure fair decision-making.

GIS allows us to analyze geographic data in order to obtain a clear overview of planning antenna deployment in Prishtina for a certain operator.

In our case, we have analyzed two station points which do not overlap with the base station positions of any operator in Kosovo. In doing so, we are able to calculate the distance between two antennas as in Figure 5 – one in Ulpiana and one in Sunny Hill. Depending on the mobile technology and the frequency at which this technology operates, we can calculate the cellular coverage and determine the coverage area.

Figure 5. Distance between Two Antennas [11]

The deployment of antennas has been presented in the GIS system layer at the main base stations providing services in the study area. The distance between the base stations has been calculated in the example above, which is d = 2.4 km.

Figure 6. Cellular Coverage Scenario [11]

By using GIS, we can propose configuration and segmentation of base station antennas as shown in Figure 6. We can directly predict the coverage area.

Figure 7. Comparison of the Coverage Area of Two Base Stations/ Identified Capacity [11]

By doing cellular planning in GIS, we will be more confident that the stations we have selected will meet the requirements for achieving maximum coverage and avoid interference when operating on the same frequency band. The number of parameters that can be studied depends on the GIS model.

We suppose that the antenna in Ulpiana emits a 50 W power signal with a carrier frequency of 900 MHz, while the one in Sunny Hill is characterized by unit amplification. If we calculate the received signal power at a distance of 2.4 km and a frequency of 900 MHz, we will have:

P_t = 50 W transmitted power f_c = 900 MHz frequency carrier

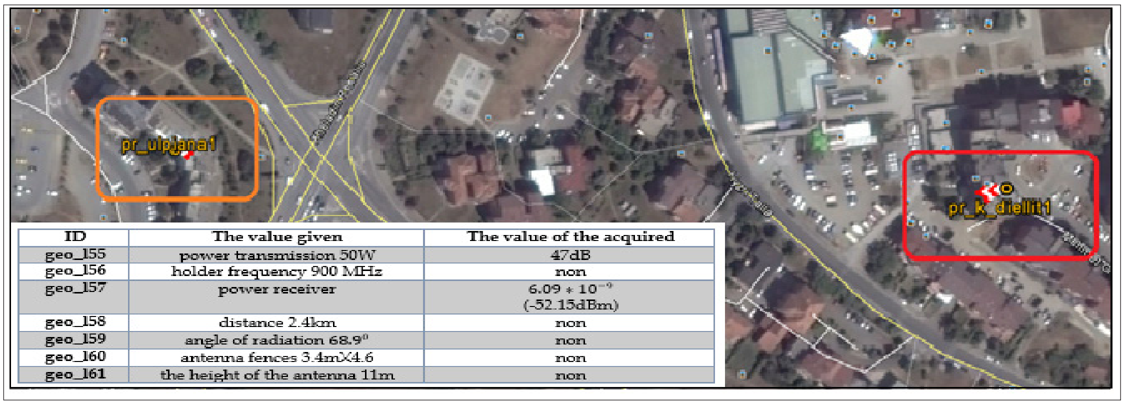
$$P_t\,(dBm) = 10\log[(P_t(W))/1(mW)] = 10\log[50\,x10^3] = 47.0dB$$

The receiver’s power:

$$P_r = \frac{P_t G_t G_r \lambda^2}{(4\pi)^2 d^2 L} = \frac{50\,(1)(1)\left(\frac{3\,x\,10^8}{900\,x\,10^6}\right)^2}{(4\pi)^2\,(2.4x1000)^2\,1} = 0.609\,x\,10^{-8}\,W = 6.09\,x\,10^{-9}W$$

$$P_t\,(dBm) = 10\log P_t\,(mW) = 10\log(6.09\,x\,10^{-6}mW) = -\,52.15\,dBm$$

The calculation of such parameters can be done through GIS, as shown in the following figure:



ID	The value given	The value of the acquired
geo_155	power transmission 50W	47dB
geo_156	holder frequency 900 MHz	non
geo_157	power receiver	$6.09 * 10^{-9}$ (-52.15dBm)
geo_158	distance 2.4km	non
geo_159	angle of radiation 68.9⁰	non
geo_160	antenna fences 3.4mX4.6	non
geo_161	the height of the antenna 11m	non

Figure 8. Values Obtained by Means of GIS [11]

What matters is the transmission power which should be controlled. The values are placed on the basis of the level of interference which should be adjusted.

3.1. Planning the Optical Fibre Extension through GIS

In this case, our objective is to set up a database (places and attributes) that can be used when planning the optical fibre extension. These data consist of all required coordinates and the interfaced location. In case of a fault, the problem is resolved very quickly. Moreover, if another operator wants to use any optical fibre, then it is analyzed through GIS to see if there is an optical fibre extension in that area.

We have taken the case of the area near the Pristina stadium as a case study of the optical fibre extension planning. Figure 9 illustrates this area.

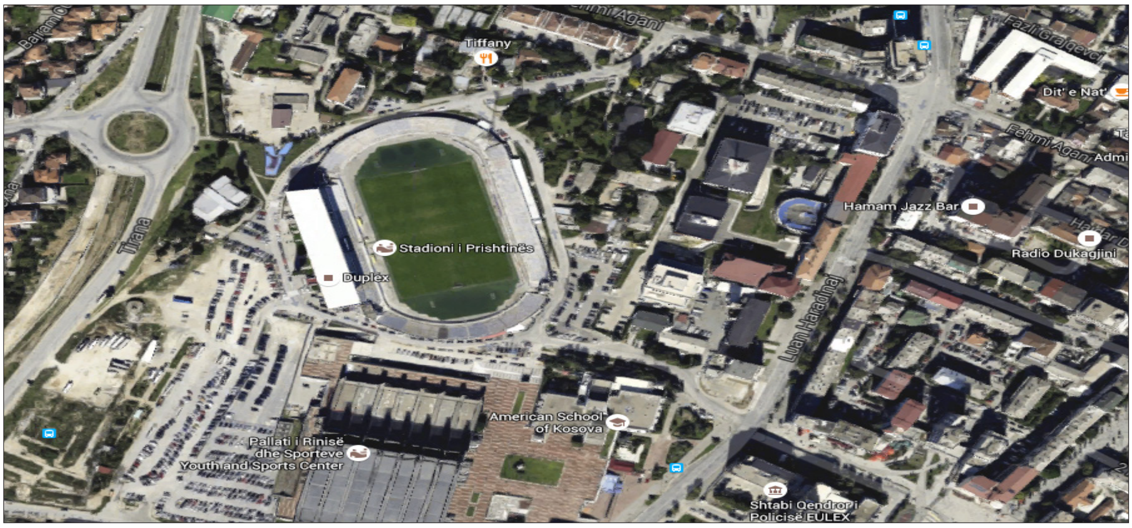


Figure 9. Planning the Optical Fibre Extension in this Area [11]

The purpose is to do interface between two optical fibre sites. Such interface is done to provide users with access to broadband services requiring high data transmission capacity. Some of the services, intended to be transmitted via optical fibre, are the Internet and digital television services.

Planning optical fibre extension through GIS should be a data source. It should represent complete, current and accurate data for a given area. These data are very important for future use. When introducing a new operator offering the above-mentioned and other broadband services, it will be of great help if such an operator can use these data. On the basis of the same data, the new operator can calculate accurately whether the joint use of the installed fibre is less costly than installing a new fibre [9, 10].

Figure 10. Interface between Sites with Optical Fibre [11]

Figure 11 presents some coordinates of optical fibre extension interfaced with a central device. The geospatial data can be found in the official system of the Republic of Kosovo, which is KosovoRef01 [12]. When all institutions process data with the same coordinate system, data matching between different layers of data provided by different institutions is to be ensured.

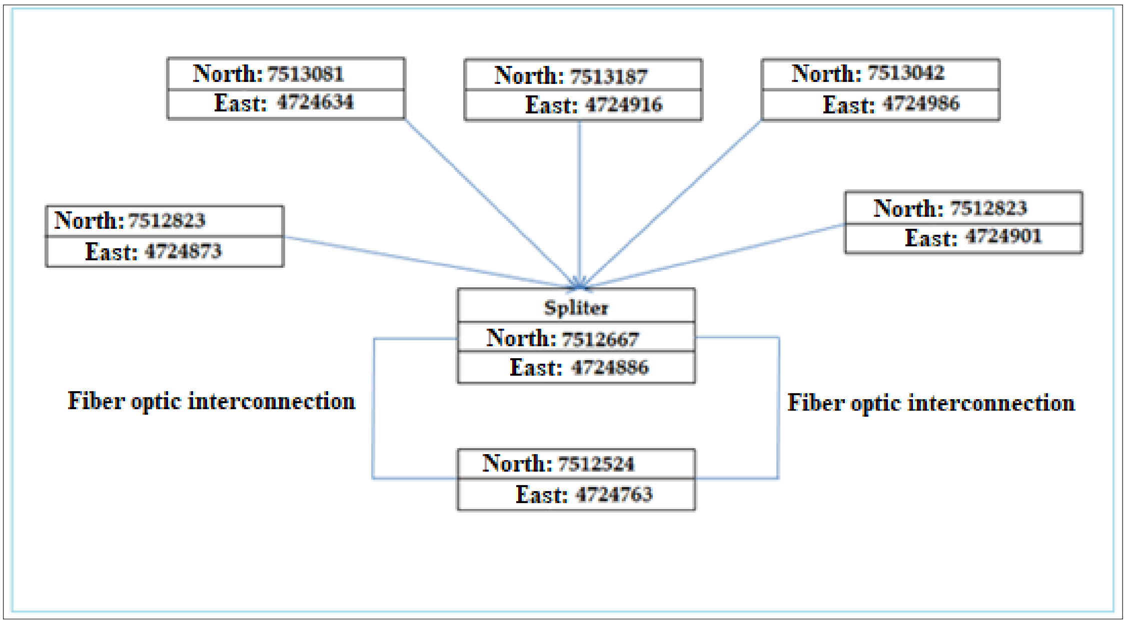


Figure 11. Coordinates of the Optical Fibre Extension

Interface between two coordinate stations realized through the optical fibre:

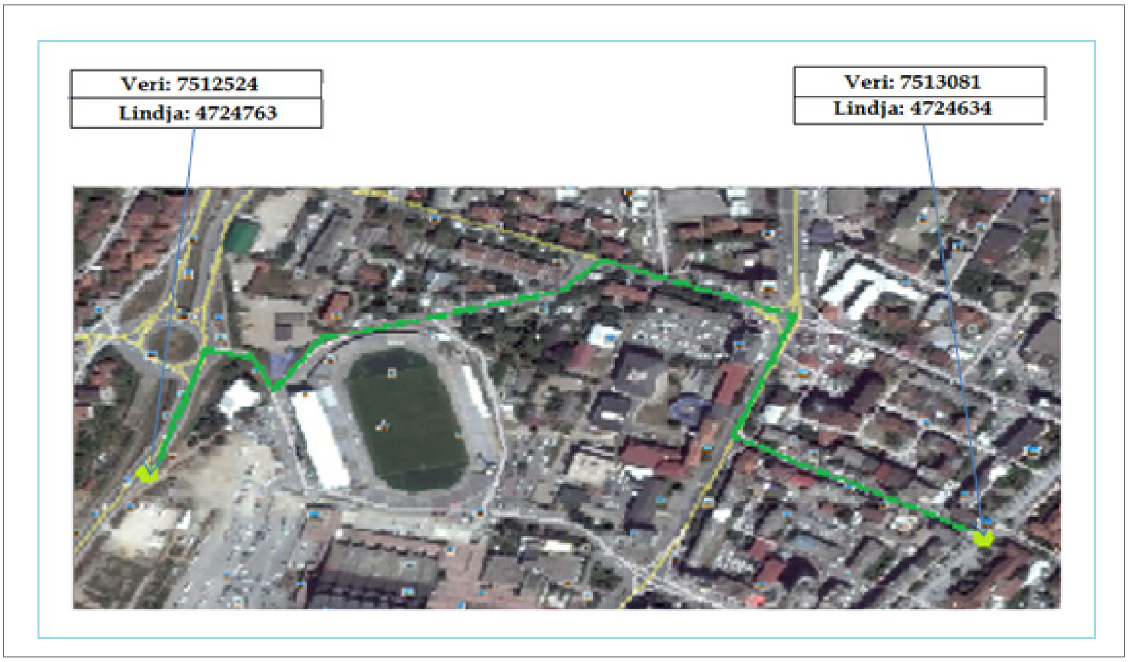
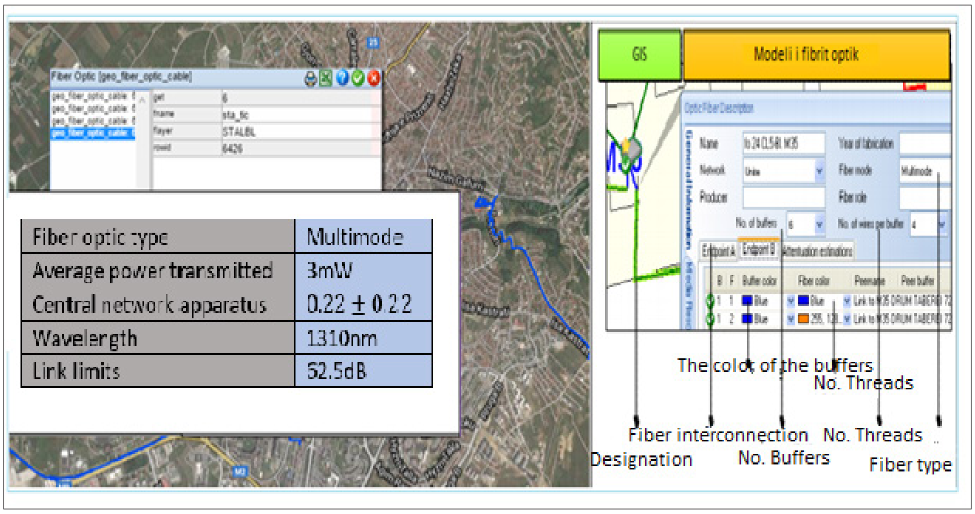


Figure 12. Interface between Two Sites

Once the optical fibre extension location has been determined, as in Figure 12, we will plan the interface distance between sites, the number of users having access to this fibre, the transmission power, the type of the optical fibre, etc. All such attributes can be calculated in the GIS system. The results are presented in Table 2.

Table 2. Attributes of the Optical Fibre [6]



Fiber optic type	Multimode
Average power transmitted	3mW
Central network apparatus	0.22 ± 0.22
Wavelength	1310nm
Link limits	52.5dB

It is worth mentioning that the determination of the optical fibre path is another important element. This is done through the ArcMap software application which is part of the GIS system [15, 21].

Before we started using GIS for optical fibre management, we used to face a number of problems concerning the accuracy of the optical fibre extension. Based on the coordinates and the team that carries out the interface points through GPS, telecommunications infrastructure planning is enabled [2]. The following table presents the properties of two optical fibre interface sites.

Table 3. Attributes of Two Optical Fibre Sites

Nr.	Site A	Site B	Distance Between Sites	The depth of the the channel	Comment	
1	Te stad.qyt. A	Te sta.qyt. B	1700 m	1.45 m	Thousands of users can connect to this optical cable extension	Interconnection between sites, Visualization, Design, Street
2	Te stad.qyt. B	Te sta.qyt. A	1400 m	1.40 m		

A number of topologies for the construction and structure of the optical fibre extension can be realized through the GIS system.

Therefore, GIS can provide an overview of the optical fibre extension. We find that GIS helps us to determine location and access the information in a database. We can also make changes or update the optical fibre layer at any time through GIS [20, 21].

The following figure shows a case of implementing a GIS program in optical fibre extension planning to make a database and a reference at any time to come back to these details again.

We plan fibre interface with one user. Let us get the interface coordinates:

Figure 13. Interface of One User with the Optical Fibre [11]

The next figure presents the placing of the coordinates in the ArcMap software. With the help of GIS scenarios and functions, we can predict the optical fibre extension and provide the spatial element.

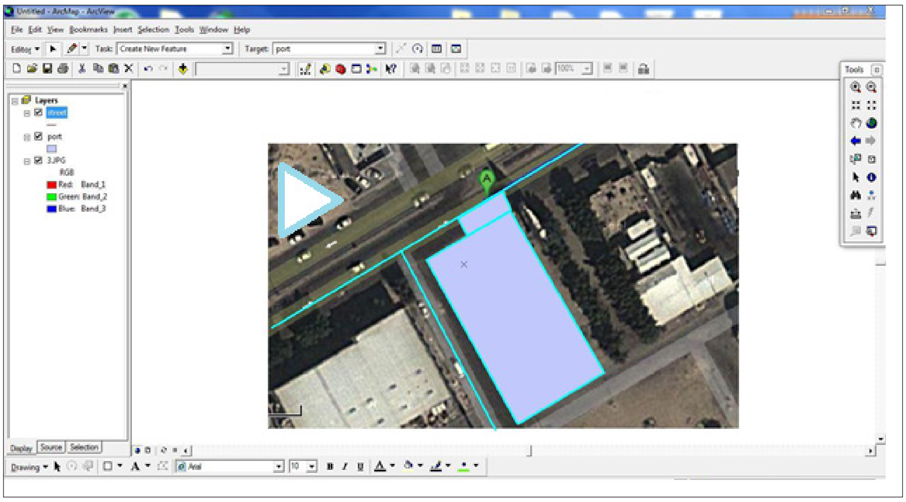


Figure 14. Placing in ArcMap [16]

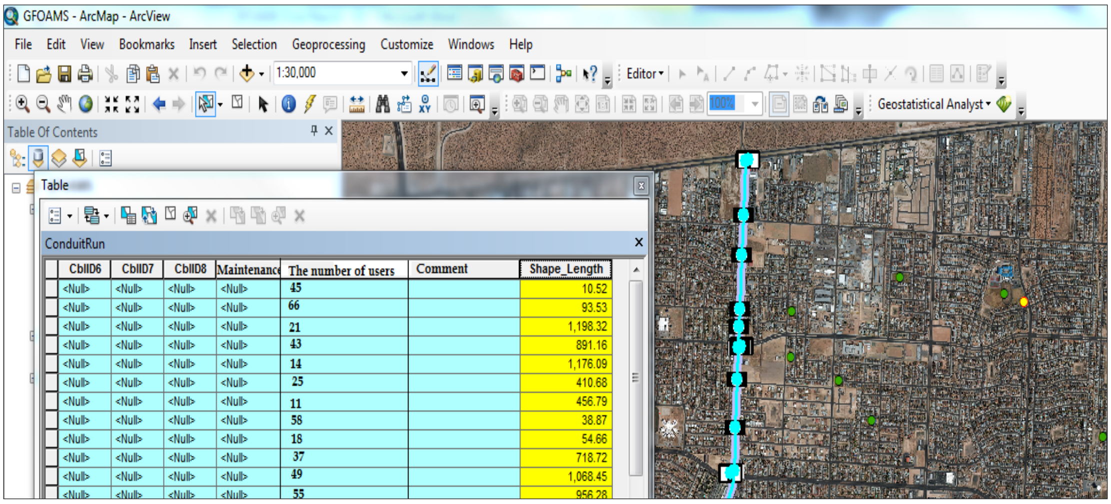


Figure 15. Generation of the Number of Users [7]

Therefore, the use of GIS allows us to plan the exact location of the optical fibre extension, as well as user interface [17, 18].

3.2. Planning Wireless Technology through GIS

In addition to wired networks, there are various technologies which enable the transmission of information between devices operating on wireless networks. Wireless technologies use electromagnetic waves to transmit information between devices.

In this case, we will focus on using the GIS system to plan the wireless network in the Lagjja e Spitalit (Hospital Neighbourhood) in Prishtina within a perimeter of 1 km, and analyze the power of the wireless signal in 3D visualization of the technology interface. The geographic information concerning the neighbourhood in question is provided in Figure 16.

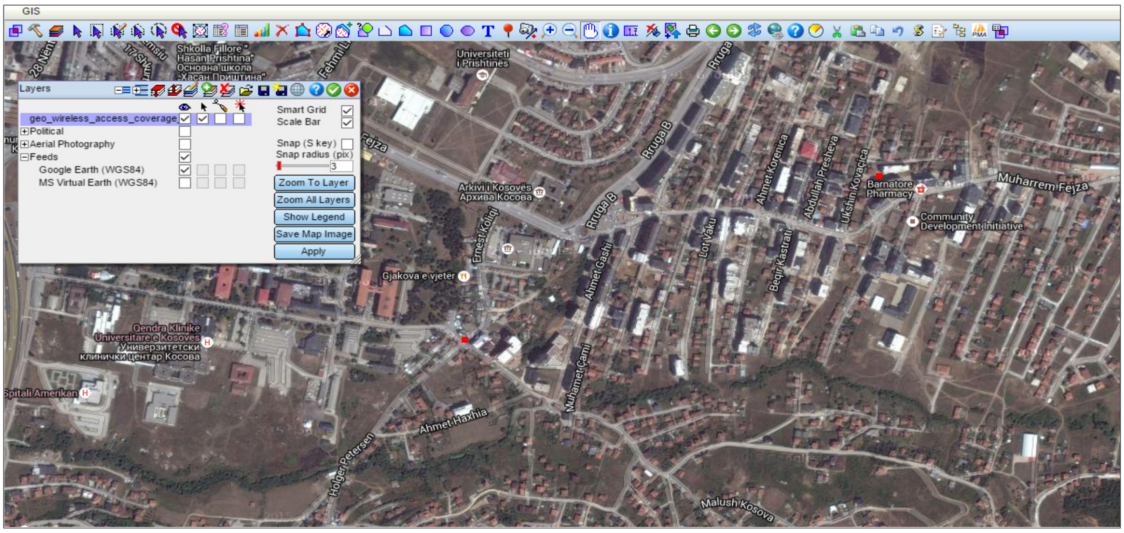


Figure 16. Geographic Information in the Hospital Neighbourhood in Prishtina [11]

Consequently, the purpose is to incorporate technical data in the transmission of online wireless signals in ArcMap and ArcScene [5] to test the GIS system in planning.

Let us plan two interface station points of the wireless signal in the Hospital Neighbourhood in Prishtina with a distance of 124 m between them.

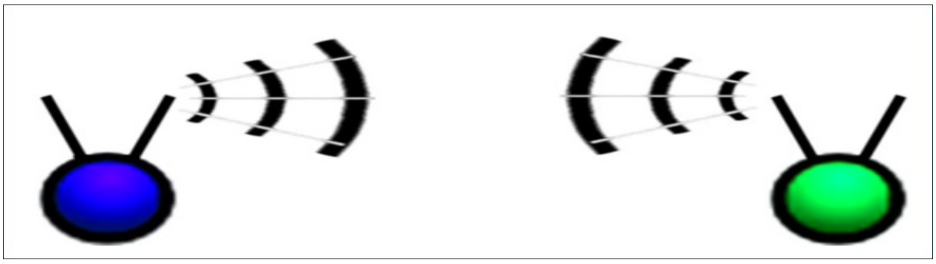


Figure 17. Propagation Points of the Wireless Signal

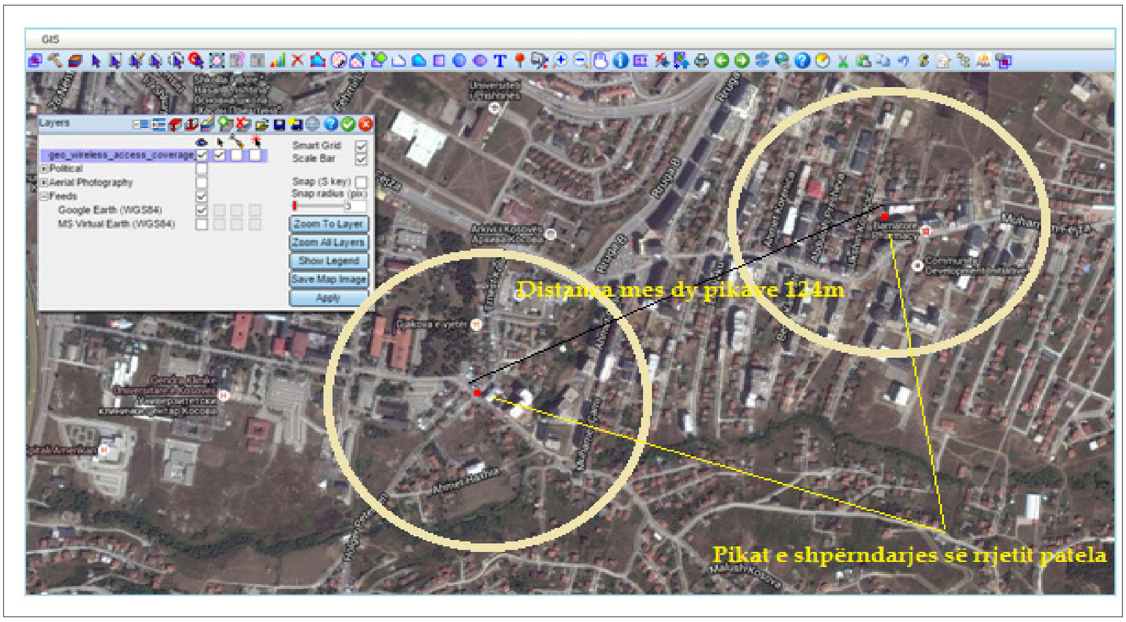


Figure 18. Distance between the Two Points [11]

The technical parameters of two devices propagating signal have been presented in Table 4.

Table 4. Technical Parameters of Both Nodes

Technical parameter	*Node 1*	*Node 2*
Modi	ad hoc	ad hoc
SSID	Point 1	Point 2
Channel	It should be compatible with one another	It should be compatible with one another
IP address	IP fixed	IP fixed

Figure 19 indicates the area of wireless signal coverage.

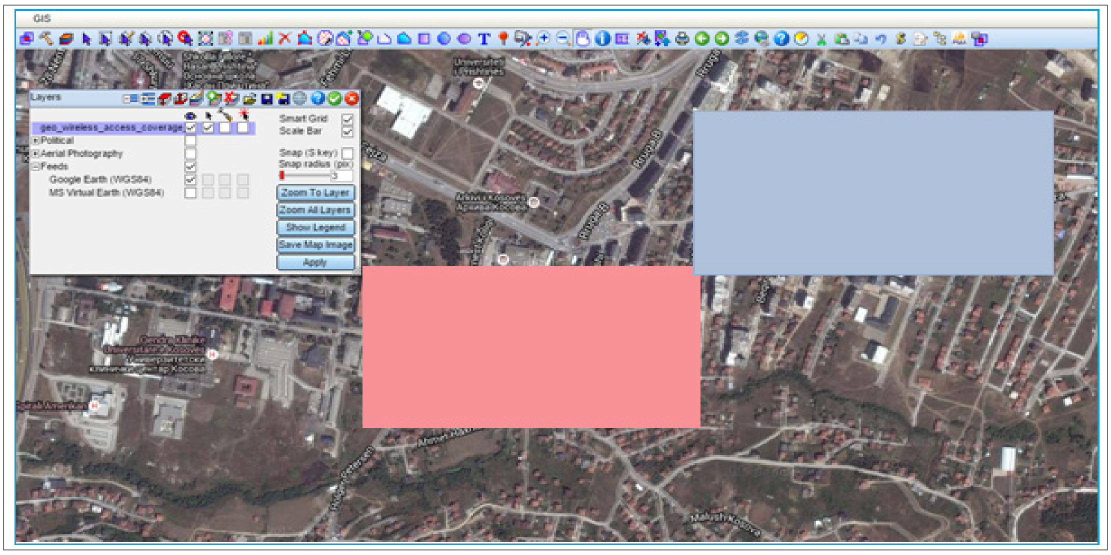


Figure 19. Determining the Area of Wireless Signal Coverage [11]

Figure 20 presents an overview of the wireless signal coverage, where the red colour represents high-level signal during propagation, while the green colour stands for low-level signal in buildings.

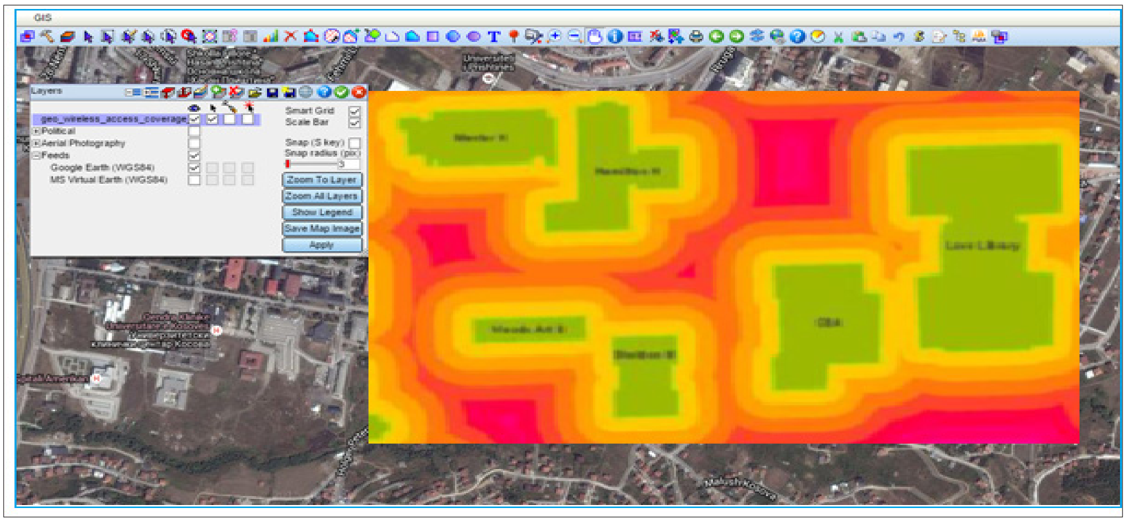
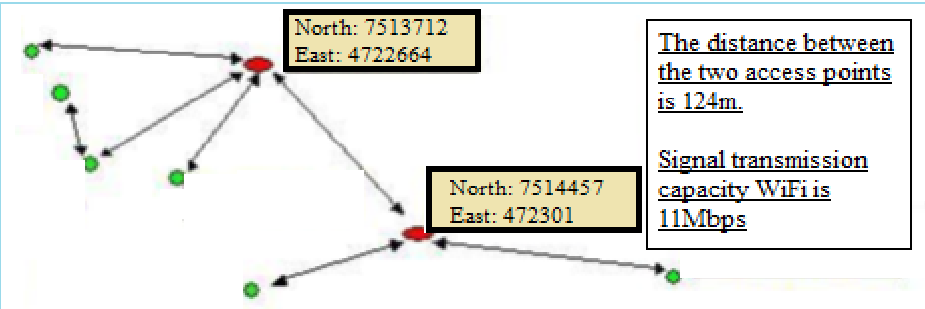


Figure 20. Wireless Signal Coverage Visibility [11]

By planning wireless signal coverage through GIS, we determine where we can have more such coverage in order to deploy Wi-Fi devices.

Table 5. Interface Coordinates of APs



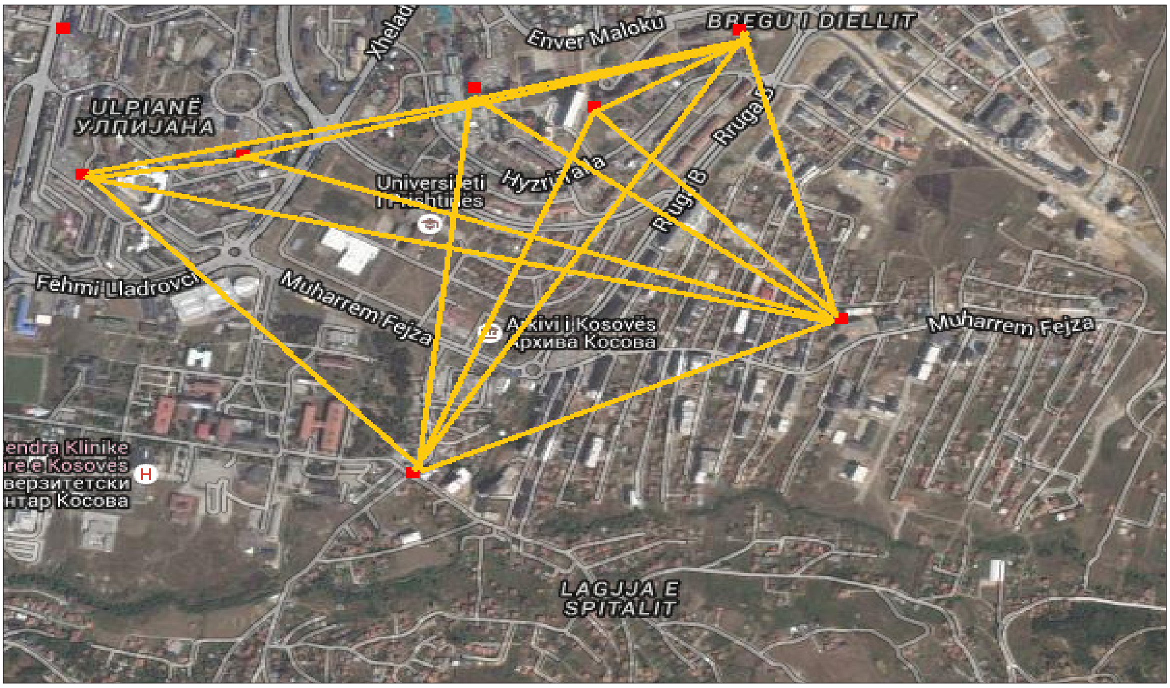


Figure 21. Interface between AP Devices [11]

Figure 22. 3D Visualization between Two APs [11]

Figure 23. Sectoral Division of Wireless Communication [11]

Compared to traditional wired networks, wireless network technologies offer many benefits. One of the biggest advantages is the ability to provide access at any time. The extensive application of wireless technology in public areas enables people to access the Internet easily and quickly, to obtain information and exchange emails and files [7, 8, 4].

Wireless network technologies also have a number of disadvantages or problems which are encountered in their application. We have listed some of them. First, wireless networks enable many operators to use unrestricted radio frequency bands within one region and thereby interfere with each another. Network safety is second [17, 11]. Wireless technologies provide access to everyone and they can be used even by those for whom they are not really designed.

Using the visual capabilities of GIS in the previous examples, we have obtained an idea of which area lacks cellular coverage, how to plan the optical fibre extension or how to realize the planning of the wireless technology, etc.

CONCLUSION

By using geographic information systems, we can evaluate, explain, analyze and perform strategic planning of telecommunications infrastructure.

Planning in telecommunications by means of GIS makes it possible for different users (telecommunications operators) to exchange information on more detailed infrastructure planning. Geographic information systems provide drafters and planning bodies with the visualization tools necessary to manage the growth and change of telecommunications infrastructure.

Information can be visualized and analyzed through a central database in order to obtain an overview of telecommunications systems. Therefore, GIS can be used for virtual access of the information concerning the antenna's radiation power, the optical fibre type, etc. With the help of GIS, problems in a given area can be monitored and identified. In addition, the most sensitive scenarios of telecommunications systems can be prioritized, and the increase of alert levels, predicting the impact on interference, can be modelled.

In this paper, a cellular coverage scenario has been developed and implemented to predict the coverage area and calculate the distance between base stations. By means of GIS, we have planned the maximum coverage and avoidance of interference. The mathematical results are generated through the geographic system.

We have presented the interface of two sites with optical fibre and we have planned the location of the optical fibre extension, interface distance, number of users with access to the fibre, the transmission power and type of the optical fibre, etc. It is worth mentioning that we determine the path of the optical fibre through GIS.

Nowadays, the development of wireless communications has been growing exponentially. The rapid growth rhythm has occurred for several reasons. The first one is related to the development of hardware systems for processing advanced numerical signal, as the global interest in broadband applications has increased. Consequently, the interface between two points of the wireless signal at a certain distance, namely the area of wireless signal coverage, has been planned in the paper. Planning wireless communications on the GIS system enables us to plan capacity, expand bandwidth, increase signal-to-noise ratio or transmission quality, etc.

Therefore, we have not envisaged to create a GIS system in this paper, but to provide answers to the planning of antenna deployment, namely to the optical fibre extension planning by interpreting the phenomena and building scenarios through this application. Wireless technology planning is also carried out through the integrated geographic system.

The paper also provides the GIS procedures and functions through which typical telecommunications planning has been performed.

REFERENCES

[1] **Gomez, A., G. Diaz, K. Boussetta** (2009). *GIS Integration with Active Sensory System*.

[2] **Saeed, A. and Bagazi, Y. Salem Obad** (2013). *Implementing GIS in Optical Fiber Communication*.

[3] **Assembly of Kosovo** (2012). Law No. 04 / L-109 on Electronic Communications.

[4] **Krasniqi, B., M. Wrulich and C. Mecklenbräuker** (2009). *Network–Load Dependent Partial Frequency Reuse for LTE.*

[5] **Drishti, B.** (2012). *GIS in Planning the Sustainable Development of a Region.*

[6] **Idrizi, B. and I. Kabashi** (2010). *New Geodetic Reference Frame “KosovaRef 01”*.

[7] **Xhin, E. and L. Zhaka** (2014). *Geographic Information Systems*.

[8] **ESRI** (2004). Geoprocessing in ArcGIS.

[9] **Albrecht, J.** (2007). *Key Concepts & Techniques in GIS.*

[10] **Delaney, J. and K. Van Niel** (2010). *Geographical Information Systems: An Introduction*.

[11] **Hoti, L. & RAEPC** (2012). *Working Procedure. Manual on the Operation of the WebGIS Platform in RAEPC.*

[12] **Demers, M. N.** (2011). *Geographic Information* Systems, 4th Edition.

[13] **Cardona Marcet, N. and A. Navarro Cadavid** (2001). *Capacity Analysis in CDMA Systems Using GIS Planning Tools.*

[14] **Cardona, N. and A. Navarro** (2009). *W-CDMA Capacity Analysis Using GIS-based Planning Tools and MATLAB Simulation.*

[15] **Khan, S. and S. Asif Kamal** (2013). GIS as a Planning Tool for the Rural Telecom, E-services and Broadband Projects in Pakistan.

[16] **Buettrich, S. and A. E. Pascual** (2006). *Basic Wireless Infrastructure and Topologies*.

[17] **Taylor & Francis**, Edited by Michele Campagna (2006). *GIS for Sustainable Development.*

[18] **Cao, Y., Y. Wang and J. Li** (2009). *A Wireless Cellular Network Optimization Platform Based on Inversion Propagation Model and GIS.*

[19] **Zhou, Y. and Dr. Nam** (2012). *Using GIS to Map the Wi-Fi Signal*.

[20] **Lifeng, Y. and Han Chen** (2010). *Study on GIS Specialty Practice Teaching System Construction.*

[21] **Shu, Z., H. Li, G. Liu and Q. Xie** (2011). *Application of GIS in Telecommunication Information Resources Management System.*

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