APPLICATION OF WIRELESS MULTIMEDIA SENSOR NETWORKS FOR GREEN BORDERLINE SURVEILLANCE

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Abstract

The security of the state borderline is one of the global concerns and main goal of every country. Intensive human involvement in application of conventional systems for border patrol is one of the serious problematic issues. In recent times, border security systems in their composition include high-tech equipment, such as: various unattended sensors, unmanned aerial vehicle, surveillance towers equipped with cameras, etc. However, these systems are faced with unsolvable problems, as regards their application along border areas with difficult terrain and covered with high forests. In this paper we will give ideas for a new system, which can be placed alongside the green borderline with a much cheaper cost and which could offer better results. In the new system for the green borderline surveillance, we propose the application of advanced sensors technology, respectively multimedia wireless sensor nodes (MWSN). This technology will have direct impact on reducing the involvement of human factor (police patrols) to the security of the green borderline and will impact on elimination of false alarms.

Keywords: WMSN; borderline; security; sensor; surveillance; architecture.

1. Introduction

Although today, in many countries of the world the trans border security has increased, yet in the world has enough conflicts and problems regarding protecting and securing of the state borders, such as Iraq, Syria, Afghanistan, etc. Problems with securing the borders have not only countries such as: Iraq, Syria, Afghanistan, but also developed countries of the world, such as: EU states, the USA, Turkey, etc., but these countries, unlike the first countries, their security border is threatened from: illegal border crossings of migrants, smugglers of drugs and weapons, etc. Therefore, each state depending on economic conditions and geopolitical factors creates strategies and policies for security and monitoring of its national borders. The security of national borders is a key element of the sovereignty of the country. Each state may have borders that are characterized by challenges that are different with those of other countries. Therefore, also the surveillance system located along the border of a country can't be appropriate for another country.

In this paper we shall analyze the challenges by which the green borderline surveillance is characterized. Today

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still many countries, realize the green borderline surveillance through conventional systems. With other words, the border surveillance is carried out by police or military patrols. These patrols carry out borderline control physically in designated time intervals and places. This kind of surveillance, except that can't provide continuous control of the border, is also very troublesome. Border security, according to this method of surveillance depends directly on the human factor. The objective of this research is to identify possible ways of increased security and efficiency of border control along the green borderline with a much cheaper cost. In this paper, firstly we will define problems and analyse possible scenarios of the green borderline. Then we will analyze techniques and existing surveillance systems which are applicable. In the third section we will offer the concrete proposals for solutions, and technology architecture proposed for borderline surveillance. In the end we will analyze the challenges by which the application of proposed technology is characterized.

2. Problem formulation and analysis of possible cases of green borderline.

2.1. Problem formulation

Today, almost all countries of the world are being faced with illegal border crossings. Illegal border crossings can be for different purposes, such as: illegal immigration, terrorism, smuggling of arms, drugs and other things of value, guerrilla (destabilization of neighbouring country), etc. Depending on the nature of illegal border crossings and roads used for illegal border crossing, each country tries to undertake measures to prevent such illegal border crossings. Therefore, border control is vital to the security of a nation and its citizens [1]. One of the technologies that are being considered to be applicable for border surveillance is the sensors technology. However, the application of this technology for the green border surveillance continually is characterized by some significant challenges such as:

- Power supply of sensor nodes;
- False Alarms (reliability);
- Failure of any of the sensor nodes and the difficulties of its replacement, etc.

Regarding these challenges, today many authors have tried to provide solutions and different proposals for these challenges in order that the sensor technology can find application for green borderline surveillance. Although today, there are some papers that have addressed these problems, yet these are the main challenges that have affected the sensor technology not to find wide application.

2.2. Analysis of some of potential cases of green border.

With state borderline is implied the line that separates the territory of a state, with other neighbouring states. This is also the state borderline. State borderline of a country can be divided into: terrestrial, water and air. **Terrestrial border** - also known as "green border" and means any borderline between that country and neighbouring countries, with the exception of official border crossing points. Green border, in many countries constitutes the main part of the border. This part of the border in many states is more problematic border, regarding application of surveillance and security systems. Before we begin with the discussion of border surveillance techniques, initially we will analyze several potential scenarios, along the green borderline such as:

Scenario 1 - These areas are more difficult for surveillance because they are composed of mountains, rocks and grasses, and are characterized by steep terrains. In such a scenario presented in the Fig. 1, the leaves will create very difficult for surveillance of the borderline by air or through long-range cameras of operation but will be very good shield for illegal border crossings.

Fig. 1. Scenario with leaves, rocks, and grasses

Criminals consider the difficulties that have the security authorities for surveillance of these areas often can be the target of their illegal border crossing. Therefore, the borderline as in the case presented in Fig. 1, entering in one of the most difficult areas for surveillance.

Scenario 2 - In the scenario presented in Fig. 2 we have presented another case of possible along the green borderline. As can be seen in Figure 2, in this scenario we have to do deal with the case where most of the border is characterized by rocks and grasses. So, as shown in Fig. 2, compared with scenario 1 and 3, this border area is stripped from forests. However, the border areas are enough steep which includes holes that are enough difficult to be monitored from the ground surveillance systems, as well as by air systems.

Fig. 2. A possible scenario along the borderline with rocks and grasses

Scenario 3 - In this scenario is presented another case of possible illegal border crossing along the green borderline, where areas along the border are covered with high forests. Such a case is respectively shown in Fig. 3, 3a and 3b. In Figure 3b, is presented a case where along the borderline, the terrain is partially flat, but covered with high forests. While, in fig. 3a is presented approximately the same case, but in this case the border area is steeper.

For the scenario presented in Figure 3, the green borderline surveillance through systems or equipment with a long-range of the operation is almost impossible. Also, the surveillance by aircrafts is unsuccessful. Namely difficulties of monitoring these areas can make these areas very attractive for criminals. Should be noted that these areas are characterized by very dense forests and many parts are almost impassable. However these areas are inhabited by very different animals that live and which create many paths that can be easily used by criminals for entering inland the country, in order to achieve their objectives.

a) A scenario along the green borderline between Kosovo - Albania

b) A possible scenario along the green borderline with very dense forests

Fig. 3. Possible scenarios along the border with high forests

Scenario 4 - In Fig. 4 is presented another possible scenario along the borderline. From Figure 4 we can see that in this case we are dealing with a borderline even and without forests. So, this is the easiest scenario possible along the borderline. In this case compared with the other scenarios, observation and security the borderline, is much easier by the Border Security Authorities. Along such a borderline can be installed and applied various technology and security systems. In this case, in other words there are no restrictions concerning the environment, compared with other cases presented in Figure 1-3, where the deployment of technologies requires commitment and high costs, and in some cases application it is almost impossible.

Fig. 4. Another possible scenario along green borderline

In this section we tried to analyze some possible scenario along the green borderline from the easiest one for surveillance (Fig. 4) to the surveillance of most difficult ones (Fig. 3) from the Border Security Authorities.

3. Existing techniques and systems for surveillance of the borderline

The security of the state border has existed since the existence of the state itself. However, the techniques of state border security has changed with time. Few years ago, security and surveillance of the state borderline has been conducted by military and police patrols. Border security is based entirely on the human factor. In this case for a full coverage of the borderline through police or military patrols it needed a commitment of a considerable number of patrols and support staff. Increasing the number of police or military patrols, supported mainly on human factor directly affects the growth of the cost. Besides cost, border control is realized in certain periods of time. So that, full control of borderline in this way is very troublesome, problematic and not to the very high level of accuracy, because the criminals very easily can detect the movements of border patrols and when they have space for illegal border crossing of the borderline, they can easily realize it.

By technology development, also the border control techniques started to change. So the state border management concept started to change itself. Therefore in order to increase the efficiency of border patrols along the borderline the technology is included as part of the border patrol. Some equipment used as part of border patrols are: various communication equipment, unmanned aircraft for detection of the illegal border crossings, mobile vehicles equipped with advanced technology, etc. Some of the equipments used by border patrols are shown in fig. 5.

Fig. 5. Some equipment as part of the border patrol

A very big assistance for border patrols has given the use of unmanned aircraft. With the better coordination of the activities of border patrol and surveillance aircraft can prevent or minimize the illegal border crossing by criminals. The use of unmanned aircraft for aerial surveillance of the border has affected in easier detection of illegal border crossings along the borderline and even after crossing the border enabled tracking of criminals. Due to the large coverage and high mobility that have these aircraft, intensive human involvement in surveillance activities, border patrols can be reduced, respectively. So the use of these aircraft directly affects in the reduction of border patrols. Thus, human resources may be engaged in other tasks, such as those of the management and analysis of information collected from equipment used for border surveillance.

However, similarly with the conventional border patrol systems, unmanned aircraft alone can't completely cover

the borderline at any time. In this case, there may be times when certain parts of the border will not be monitored by such devices [2]. These aircraft can't constantly keep under surveillance the borderline or must engage a large number of them. Also, the involvement of aircraft for surveillance of borderline for the case of the scenario 1 and 3, doesn't give good results because very easily criminals can cross the border without being detected by the aircraft. In other words, the engagement of aircraft for border surveillance, offers enough uncovered spaces that the criminals can use for border crossing. Moreover, unmanned aircraft have considerable cost and requires very specialized staff in monitoring the activities of these aircraft. In addition, bad weather conditions such as rain and snow may have the effect in limiting of their supervision skills.

Taking into consideration these issues that we have addressed, we could conclude that the use of these unmanned aircraft, nevertheless to the high cost, allow enough areas that can't be under surveillance and which can be used by criminals for illegal border crossing. In order to conduct the best possible surveillance of the border line the surveillance towers with long-range operation are used. However, these surveillance towers are suitable for areas where there is visibility. These towers are suitable for those areas that are approximately as in Scenario 4. Surveillance towers are not suitable to apply in those cases as in Scenario 1 and 3. Therefore in order to find a solution for those cases where existing technologies do not provide solutions, in last decade the use of WSN technology along the border line is meant to be used. This technology, from some authors, is intended as additional technology of existing technologies. Today, regarding the application of WSN technology along the borderline, we can find some research and concrete proposals.

In [2], hybrid architecture of wireless sensor networks is presented for application along the state borderline. This system architecture of BorderSense has three layers. The unattended ground sensors and the underground sensors constitute the lower layer of the architecture, which provide higher granularity for monitoring. At the second layer, surveillance towers improve the accuracy of the system through visual information. Finally, mobile ground robots and unmanned aerial vehicles constitute the higher layer that provides additional coverage and flexibility. This architecture is appropriate to be applied, mainly in those border areas, as in Scenario 4 or similar. Namely it is appropriate in those areas that aren't characterized by steep terrain, and covered with dense forests, as in Scenario 1, 2 and 3. The application of such a system for scenario 1, 2, 3 is a cost, almost unbearable and very equipment included in this system are unnecessarily.

In [1], authors have studied the Turkish border security system via simulation to identify possible ways of increasing border control and security along the land borders.

In [3] authors FemtoNode and the adaptable middleware platform for military surveillance have presented. In order to illustrate the use of the proposed platform infrastructure, i.e. the customizable FemtoNode and the adaptable middleware, from authors an area surveillance application is studied. In this application, low-end sensors nodes are scattered on the ground along a borderline. In case of an unauthorized vehicle crosses the borderline limit, the sensors issue an alarm which will trigger the use of Unmanned Aerial Vehicles (UAVs) equipped with a more sophisticated sensors, such as radars or visible light cameras, in order to perform the recognition of the vehicle. However, this studied platform isn't appropriate to apply for the borderline cases that are presented in scenario 1, 2, and 3.

In [4], authors have proposed a Energy-efficient routing algorithm, for the case when WSN are applied along the borderline. Routing algorithm will be extended to sleep mode and therefore a longer network lifetime can be achieved. Then the Degree of Aggregation algorithm DOA means the minimum number of reports about an event that a leader of a group waits to receive from its group members, before reporting the ship location to the base station.

In this section we analyzed some of the papers which dealt with the application of WSN along the borderline, and the problems of their application. However, it should be noted that today there are many other papers that dealt with different problems of WSN, but which we haven't analyzed in this paper.

4. Results and discussion

In this section we will propose a new method of application of sensor technology along the green borderline, which will provide an increase security performance along the state green borderline. As per discussion, existing technologies do not provide an appropriate solution for increased security along the green border line. Moreover the application of existing systems along scenarios 1, 2, and 3, are with a high cost or almost impossible to be applied.

If we analyze scenarios 1 and 3 we can see that we have to deal with the border areas which are characterized by high and very dense forests along which is very difficult to pass. However, through these forests may have multiple paths that can be created from wild animals which can be present in such forests. Also, these crossing paths can be created by human factor for various purposes of exploitation of these forests. These paths created by animals or human factor can be used easily by criminals for smuggling. On the other hand, these paths will be almost impossible to be monitored 24 hours from conventional border patrol or unmanned aircraft. Also application of surveillance towers is unsuccessful because through these towers is impossible to be realized surveillance of such paths as a result of high forests.

Unlike the scenario 1 and 3, scenario 2 is characterized by steep areas, but without high forests, where the visibility is better. In the areas that are of the type of scenario 2, we can also apply to existing technologies analyzed in this paper, such as surveillance towers, unmanned aircraft, etc.

Fig. 6. The architecture of a multimedia sensor node.

In order to monitor these paths along the forests with very steep terrains and high forests or for monitoring the green borderline, in this paper we propose the application of a new method. In this new method for surveillance of these paths and green border line, WMSN is used. Communication WMSN based on IEEE 802.15.4 protocol [5, 6]. The architecture of a WMSN is presented in fig. 6. This node consists of: **Sensing unit** - this unit include: A / D, scalar sensor and thermal camera. The function of this unit is the capture of images in space observed by the camera; **Communication Unit** - This unit enables the communication of sensor node with other nodes in the network. Also, this unit allows the sensor node that information captured from the surroundings to send to the desired destination; **Power Unit - Battery** - This unit serves as an energy source for other units of the node; **Processing Unit** - This unit includes the CPU and memory. This unit enables information processing and storage of information; **SIM card** - it could be any of the operators of telephony, etc.

The images captured by the sensor nodes, routing through the network to the nearest police station, and then sent to The central security monitoring room [7, 8] for analysis of information. After analyzing the information collected, depending on the results of the analysis has been realized by sending information relevant to patrol units. The network architecture for WMSN along the green borderline is presented in the figure 7.

Fig. 7. The proposed network architecture for WMSN

From Fig. 7, we can see that the network architecture is divided into three parts. The first part includes the green borderline, or end network. The second part includes the end buildings of the police stations, which are nearest along the borderline. The third part is the central monitoring room. The communication Node-Sink-Police Station is realized through microwave network. Communication between Police stations can be realized through optical or microwave network.

Application of WMSN for the purpose of enhancing security along the borderline, affects the reduction of other

sensor types. If we analyze, scenario 1, 2, and 3, we can see that in those areas, it is impossible for vehicles to cross. The opening of underground tunnels is also something unaffordable by interest groups. Therefore, it isn't necessary for the application of seismic sensors, along the green border. Since we propose the application of multimedia sensor, also it isn't necessary for the application of pressure sensors.

Placement of such a system, along the green borderline, can have direct impact in the efficiency of border police or military patrols through continuous information about the possible illegal border crossings. The intervention patrols will be realized only after the captured images are analyzed. This technology eliminates false alarms, which have been a major concern of sensor nodes. On the other hand, the cost of application of this technology will not be very high. WMSN could be placed along the borderline completely or only in those hot spot areas and paths where border authorities determine that can have illegal border crossings. A deployment of such technology directly affects reducing border patrols.

4.1. Area of coverage of a wireless multimedia sensor node

In this section we will analyse the coverage of the borderline through WMSN distribution. The radius of coverage of a multimedia sensor node depends on the type of sensor, the purpose and place of deployment. However, we will examine the potential coverage area of a WMSN node which is characterized by a rotation angle of 360 degrees. These sensors offer a multidimensional coverage. The area which is covered directly by the sensor node is called as Field of View (FOV). The radius of coverage of a sensor node and FOV are shown in fig. 8. FOV is calculated by the formula:

$$FoV = 2 * \text{atan}\left(\frac{h}{2r}\right) \quad (1)$$

Where: h - is the horizontal FOV; r - radius of coverage.

The proposed multimedia sensor node for application is considered to have a rotation angle of 360 degrees in the horizontal direction and an angle of rotation of 35-108 degrees in the vertical direction.

Fig. 8. Schematic presentation of the distance and FOV of a multimedia sensor node

For the monitoring of green border, through the application of multimedia sensor nodes, we propose the distributing sensor nodes, as in Figure 9. This case foresees that the sensor nodes should be deployed in a strip along the borderline, one after another. Each sensor node is responsible for detecting, analyzing and reporting on movements across the area covered. Formula to find the necessary number of sensor nodes to cover the border line is:

$$d = 2r * n \Rightarrow n = \frac{d}{2r} \quad (2)$$

Where: r-radius of the sensor node; n - the number of sensor nodes; d- length of the borderline.

If a sensor node has a coverage radius of 13 m. To cover a distance of 1 km of the border line with node sensor, the required number of sensor nodes is 39. This logic is not valid for coverage paths along the forest. Placement of sensor nodes, along paths is realized depending on the need and forecasting of border authorities.

Fig. 9. Sensor nodes deployed in a strip along the borderline

4.2. Challenges by which the WMSN application is characterized

Placement and functioning of WMSN along the border line or in specific areas along the border line is characterized by several challenges, but we will discuss some among the most important, such as:

- Network infrastructure;
- Placement and maintenance of sensor nodes;
- Power supply of sensor nodes;
- Damage of sensor nodes from animals or human factor (criminals), etc.

Network infrastructure - for multimedia sensor node operation, initially border areas should be covered by the network infrastructure. For the case scenario 1, 2, and 3 of the border area coverage network, are easier through any of the wireless technologies.

Multimedia sensor nodes placement - placement of NMS should be realized by human factor, manually. Thus, placement and maintenance of sensor nodes, along steep areas is difficult. Placement the sensor nodes can be realized in these areas, along the borderline, specific areas along the borderline or in certain parts across paths. The place and position of the sensor node placement must be determined and realized from the experts of the border authorities.

Power supply of sensor nodes - lifetime a sensor node is directly dependent on the power supply (battery node). On the other hand, sensor nodes should be placed along the border areas that can't be accessed by military machinery. Therefore, manual battery replacement sensor node is one of the main challenges. With the aim of saving of energy, sensors should stay in inactive state during the time when there isn't movement and active state at the moment when are detected movement in the area covered by the sensor node. Also, captured images from the sensor nodes should be converted to black and white images "in press" [9] so that power for transmission of image and loads of transmission link to be minimal. In this case, we will have a minimal consumption of electrical energy from sensor nodes.

Damages to the sensor nodes from the animal or the human factor - can happen that the sensor nodes are damaged by the animals during their movement through paths from one side to the other side of the borderline. However, damage of the sensor nodes can also occur by the criminals so that they can realize crossing the border without detected of border security authorities. So should these sensor nodes to be replaced by border security authorities, but the replacement can't be done immediately. But usually the placement of sensor nodes should be realized in such a way that each sensor node should protect the other sensor node. So if a node is damaged, other node which is located in the same path, but in another position can replace the damaged node.

We should note that although the proposed system and technology is characterized by several challenges, the impact of this technology in increasing the efficiency of border patrols in preventing crossing of criminals along the borderline is considered to be satisfactory. Also, the design and implementation of such a system for surveillance of the green border can be realized in not such a high cost. On the other hand, this applicable proposed technology resolves the problem of false alarms (false alarms can be verified immediately) which has been one of the main factors that have prevented the application of sensor technology for the purposes of border security.

By comparing existing systems for surveillance the state border with the proposed system and method we can see that the proposed system compared to other systems and technologies offers a very suitable solution. Moreover, the proposed system, except that can be applied with a low-cost, offers choice for many existing concerns regarding application of sensor technology along the green border.

5. Conclusion

In this paper, we presented a new system and method of surveillance the green borderline for border patrol, to reduce intensive human involvement and to improve the detection accuracy of illegal border crossings. This proposed architecture includes application of WMSN having a direct impact on the elimination of the problems that have existing systems for green borderline surveillance.

Application of WMSN effects on increasing the efficiency of border patrols to the detection of illegal border crossings and impacts on reducing of intensive patrols. In other words, the technology proposed WMSN border surveillance affects the elimination of problems that sensor technology has regarding the large number of false alarms. Patrols will be activated and will react only after they have received and verified images captured from sensor nodes.

In the future we will design an algorithm which will enable multimedia sensor nodes to be able to make the difference between animals and humans. This will have direct affect in electricity saving to the sensor nodes and also will affect the reducing of load transmission link. Also, after the designing of the algorithm in order to test the system performance, the real tests will be conducted.

6. References

- [1]. Çelik, G. and Sabuncuoğlu, İ. (2007). Simulation modelling and analysis of a border security system. *European Journal of Operational Research*, Vol. 180, No. 3, pp.1394-1410. Ankara, Turkey. Elsevier.
- [2]. Sun, Z., Wang, P., Vuran, M.C., Al-Rodhaan, M.A., Al-Dhelaan, A.M. and Akyildiz, I.F. (2011). BorderSense: Border patrol through advanced wireless sensor networks. *Ad Hoc Networks*, Vol. 9, No. 3, pp.468-477. Elsevier.
- [3]. Freitas, E. P., Allgayer, R. S., Wehrmeister, M. A., Pereira, C. E., & Larsson, T. (2009). Supporting platform for heterogeneous sensor network operation based on unmanned vehicles systems and wireless sensor nodes. In *Intelligent Vehicles Symposium*, pp. 786-791. IEEE.
- [4]. Babu B. Swaminathan A, D. C. Joy D.C. Boarder Analysis with Ensora and Doa Using Wireless Sensor Networks. *International Conference on Emerging trends in Engineering and Technology*. ISSN: 2248-9622, pp.76-83.
- [5]. Nedelcu, A. V., Duguleana, M., & Sandu, F. (2014). Evaluating the Energy Overhead Generated by Interferences within the 2.4 GHz Band for a Hybrid RFID Network. *24th DAAAM International Symposium on Intelligent Manufacturing and Automation, 2013. Procedia Engineering*, Vol. 69, pp. 210-215. Elsevier.
- [6]. Cvitić, I., Vujić, M. and Husnjak, S., 2016, January. Classification of Security Risks in the IoT Environment. *DAAAM international symposium on intelligent manufacturing and automation*. ISBN 978-3-902734-07-5. ISSN 1726-9679. pp.0731-0740. Vienna, Austria
- [7]. Shehu, A. and Hulaj, A., (2013). The analysis of delays in the network for video and voice applications through OPNET software package", *Advances in Circuits, Systems, Telecommunications and Control*, ISBN: 978-960-474-341-4. France, Paris. WSEAS.
- [8]. Hulaj, A., and Shehu, A., (2014). Optimization of network delays through implementation of EIGRP routing protocol, *International Journal of Computers and Communications*, Vol. 8. NAUN.
- [9]. Shehu, A., Hulaj, A., and Bajrami, Xh., (2016). An Algorithm for Edge Detection of the Image for Application in WSN, *Applied Physics, System Science and Computers (APSAC 2016)*, Dubrovnik, Croatia, September 28-30, "in press" Springer.