

DOI: 10.7251/VETJEN1801132M

UDK: 639.1.02:004.35

*Review scientific paper*

## ICT SYSTEMS FOR MONITORING AND PROTECTION OF WILDLIFE IN THEIR NATURAL ENVIRONMENT

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**Abstract:** The paper deals with systems for monitoring and protection of wild animals in their natural environments and the use IoT technologies and solutions in protected nature reserves. The paper also examines the reasons and possibilities for implementing the above mentioned technical solutions, especially in terms of protecting species from the red list of endangered species. In this sense, the paper also discusses technological solutions and the possibilities of applying IoT working framework, the concept of the Internet of animals, and the application of these technologies through various business and research models. Finally, the paper provides examples of solutions from the point of view of the necessary infrastructure (servers, storage, internet, animal necklaces, stationary cameras and drones), as well as from the point of view of data processing and the legal framework for the application of these solutions.

**Key words:** IoT, wild animals, endangered species

### INTRODUCTION

The problem of research, but also the popularization of wildlife in their natural ecosystems today, is gaining on its actuality for several reasons. The main reason for this increased interest in field research of wildlife in their natural environment lies in the possibilities

of remote tracking of animals, but also the processing of results and measurements, which are possible with new ICT technologies, and in the fact that due to industrial development, a large number of natural environments of these animals simply disappeared as

a consequence of the construction of civilian infrastructure and the increased needs for the living space. In this way, the living space of wild animals is reduced, and thus the ecosystem's ability to provide living space, food and other vital needs for a certain number of animals. These processes are unsustainable and lead directly to the extinction of certain endangered species, predominantly predators, which are at the top of the food chain in an ecosystem. As the chances of finding food decrease, wild animals might desperately seek food outside of limited and isolated ecosystems which increases the possibility of an encounter between wild animals and people. This leads to a new pressure, for farmers who are directly affected by this behavior of the predators, as well as for the ecosystem itself, because taken actions include hunting which limits the number of predators making it constantly reduced and the mentioned species is soon coming to the brink of extinction. As everything in nature is connected, this has unimaginable consequences for the entire ecosystem which over time collapses and in a relatively short time transforms into a civil park whose characteristics are in line with the expectations of the population and serves as a recreation space instead of a living space for endangered species which was his original purpose.

The ability to monitor wildlife in their surroundings helps prevent these situations and this is one of the main commercial reasons of increased

interest in techniques and technology for monitoring wildlife in their natural environment.

Another important factor causing increased interest and the use of animal tracking techniques, is reflected in the activities of the groups for the protection of endangered species that try to ensure the survival of wild animals in restricted and de facto dysfunctional ecosystems in a way that it is regulated by nature.

The third important factor is definitely the attempt of the biologist to study the behavior of wild animals in a way that thanks to new non-invasive technologies they follow them from a distant location avoiding any possible interaction with the ecosystem as such, and in that way they conduct an adequate investigation of the behavior of both individual members and groups of animals, paying special attention to the social and territorial behavior of wild animals. With this in mind, we should emphasize the following: in order to learn about the life and behavior of wild animals, so far we have been limited to individual observations and biological expeditions. A biologist would enter an ecosystem trying not to disturb it by his observing and studying while hoping to discover patterns of wild animal / species behavior and its interaction with other elements or species within the ecosystem. This method of studying animals, apart from being long-lasting, uncertain and extremely tough for the researcher, is also based on the most economically advantageous model.

The entire research is based on the expectation that an individual will be able to see, classify and sort key events in an acceptable time and at an acceptable price. He should also be able to learn and understand the behavior of a group of observed animals, recognize the patterns, draw conclusions and formalizes the acquired knowledge by establishing scientific principles that are essentially logically consistent, verifiable and provable. It should be emphasized that the primary requirement regarding the understanding of the animals' behaviour is related to the knowledge of where the animal is and what it is currently doing, because this knowledge, monitored and recorded over a longer period of time, is the basis for further study. Based on the aforementioned, the natural necessity for food, water, movement, rest, and other physiological needs and habits can be crystallized by a diligent analysis.<sup>1</sup>

This practice of primarily biological studies of wild animals began to change somewhat during the 1960s when, for the first time, monitoring methods based on the equipping monitored animals with adequate active or passive tags (collars, marking ring) began to be used, along with a radiogoniometre to approach the location and determine the position and daily walk of the animal.

The fourth factor causing an increased interest in wildlife monitoring

technologies is reflected in the fact that, thanks to the mentioned technologies and the application of other ICT technologies, the mentioned ecosystems and animals can be presented in a more adequate way, which is interesting both from the commercial point of view and at the educational level. This trend will grow as the demographic structure of the audience, to which such content is intended, is changing. Young generations experience the perception of reality through social networking technologies, that are applicable to animals in an ecosystem, rather than in direct contact with those animals. Thus, the question of the establishment and preservation of national parks is reduced practically to the recognition of the function of the same, that is, on the presented reasons for their existence and managing, that is, the way in which animals are treated within them, and what popularity they could achieve on global information market.

This practically means that the survival of individual national parks and the animal world in them, especially when it comes to large predators from the top of the food chain, depends on an adequate presentation of them, through ICT technologies, primarily social networks and profiles, as this is the way in which the modern population not only perceives reality, but also decides on the needs and conditions of funding them.

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1 W. W. Cochran, D. W. Warner, J. R. Tester, V. B. Kuechle, Automatic Radio-Tracking System for Monitoring Animal Movements, Reprinted from BioScience, Vol. 15, No.2, 1965, pp 98-100, available at: [https://www.researchgate.net/publication/247840577\\_Automatic\\_Radio\\_Tracking\\_System\\_for\\_Monitoring\\_Animal\\_Movements](https://www.researchgate.net/publication/247840577_Automatic_Radio_Tracking_System_for_Monitoring_Animal_Movements)

### **Other social impacts that affect the need for better observation of animals and their behavior in the natural environment**

The activities of the animal protection groups have created pressure on zoos and animal users to provide a more natural environment for animals in this type of detention, both in terms of habitat and in terms of the social environment and nutrition. To ensure this, many zoocentres now create simulated natural habitats and observe the social abilities and behavior of even the most common animals.<sup>2</sup> This initiative for protecting wildlife in zoo gardens, has led to an increased need for these same animal species to be studied in their natural environments in order to respond to the requirements, set up by groups for the protection of animal rights, in terms of keeping them.

The problem of hunting, fishing and managing hunting resources in areas not under a special protection regime (forests, mountain hills) is reflected in an insufficiently clear methodology for the determination of hunting quotas, which often do not correspond with any recognized methodology but with the current needs of civil society around these ecosystems.

In the areas outside protected nature reserves, large predators' survival

depends on the management of local interests, both the interest of hunting associations and the interests of local farmers. One of the serious problems, especially when it comes to predators from the top of the food chain, which are also the most endangered ones One of the serious problems, especially when it comes to predators from the top of the food chain who are also the most endangered because they tend to remain without enough food, is reflected in the fact that they, in our area especially wolves and bears, are trying to look for food outside forestry farms where they are still imperceptible and therefore protected from hunters to some extent. If a wolf attacks a domestic animal, in the first place the cattle on pasture, not only he will be hunted, but probably many other members of the pack. They are automatically proclaimed vermins and the most restrictive measures are taken toward all the members of the same species. The systems for continuous remote tracking of predators represent a possible solution to this problem, as this creates a constant insight into the behavior of animals and their presence in a certain territory, and it is possible to create preconditions for releasing the same from the stigma of guilt for cattle attacks. In this case, it can be said that there is a strong social aspect of the use of animal tracking technologies, since the

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2 ERIC SCHMITT, 'Natural' Habitats Offer Insights Into Social Behavior of Animals, The New York Times, January 26, 1988, dostupno na mreži: <http://www.nytimes.com/1988/01/26/science/natural-habitats-offer-insights-into-social-behavior-of-animals.html>

release of animals from a social point of view also means freeing people. Several authors emphasize that problems related to the ecological crisis that has become global are due to anthropomorphic point of view and personal interests and that in order to preserve the existing protected ecosystems it is necessary to change this view of the world.<sup>3</sup>

Due to the continuous civilization progress, there are land conversions. Due to the interruption of natural cycles and the process of violent urbanization, the land that was previously part of a special ecosystem rapidly depletes to the level of its transition to completely uninhabited land which leads to desertification.

According to Allan Savory, a biologist, this process can be prevented if the land is used to mimic the natural fluctuations of ecosystems. He claims that the predators' role is to force animals they feed on to move, and thus they do not realize local influence in terms of polluting their environment beyond the limits of self-sustainability of an ecosystem. In this way, the predators actually enable the survival of a complete ecosystem with all kinds in it. Removing the predator from the ecosystem will not

save any protected species, and in the long term it will lead to the collapse of this ecosystem into desertification land.<sup>4</sup> From this point of view, it becomes clear how important it is to have a real and regular insight into the movement and behavior of wild animals, especially predators, because by mimicking natural cycles, part of the desertified soil can be recovered into self-sustaining ecosystems in a shorter period of time.

Many countries today face the need to harmonize and organize public health, cattle health and wildlife health. Occurrences such as diseases that spread from natural habitats to urban environments are no longer so rare, as we've witnessed with bird flu, hantavirus, and Western Nile virus. Faced with the need to protect natural ecosystems, as well as their own population, many countries, such as Canada, have set up special agencies to track wildlife mortality, look for its causes, foreknow and try to reduce the risks for public health.<sup>5</sup> Such widespread networks enable healthcare organizations to work preventively rather than reactively, and largely avoid and reduce the negative effects of biological hazards that come

3 Jessica Ellis, Mel Hall, Phil Ong, Leif Wege, Natalie Paterson, Chelsea Smith, Animal Testing at Dalhousie University: A brief insight into social, economic, and environmental effects of nonhuman animal testing, Dalhousie University, 2010, available at: <https://www.dal.ca/content/dam/dalhousie/pdf/science/environmental-science-program/ENVS%203502%20projects/2010/AnimalTesting.pdf>

4 Allan Savory, How to green the world's deserts and reverse climate change | Allan Savory, Published on Mar 4, 2013, video, 02.03.2017, available at: <https://www.youtube.com/watch?v=vpTHi7O66pI>

5 Tyler Stitt, Julie Mountifield, Craig Stephen, Opportunities and obstacles to collecting wildlife disease data for public health purposes: Results of a pilot study on Vancouver Island, British Columbia, Canadian Veterinary Journal, 2007 Jan; 48(1): 83–90., available at: <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1716737/#>

from wildlife. The basic precondition for the operational work of such agencies is the widespread sensor network both in ecosystems and on the very animals. Only the data collected in that way have sufficient density, and we can rely on their accuracy to avoid the assumptions of the suspicious accuracy that today dominate this field due to insufficient data, that is, the collection of data only when a phenomenon has already become recognizable.

Remote animal tracking technique is a key technology that provides the gathering of necessary data both in real time and in terms of the historical log, so it can be subjected to Big Data analytics techniques that provide a satisfactory level of predictive accuracy, but can also be used as tools to search back to the source of the infection or find a biological hazard and trigger that has led to the onset of the disease.

The process of protection and legal measures for providing legal, organizational and operational activities for the protection of endangered species

The process of protection of an endangered species begins with its identification and recording, and the assessment of threat for the purpose of making the Red List of Threatened Species. The Red List is an indication of the level of threat of certain species in a given area. These lists are dynamic in nature and are continually updated, that

is, they change according to changes in the field. It is especially important to note that the level of threat increases with the decrease in the natural spread of the species, ie growing in the case of endemic species.

The largest number of endangered species is endemic, ie narrowly localized in the distribution and ecologically stenovalent, and the disappearance of such species can not be compensated from another reserve “genetic source, as is the case with regionally disappearing species that can be reintroduced from of the preserved populations somewhere else.<sup>6</sup>

Unfortunately, in Bosnia and Herzegovina, there are still no Red Lists at the state level. In RS, a list of protected species was adopted in 2012, entitled “Red list of protected species of flora and fauna of the Republic of Srpska” (“Official Gazette of RS” No. 124/12) in which the categories of endangered species of certain species are not given. On the other hand, in 2014, the “Red List of Wild Species and Subspecies of Plants, Animals and Mushrooms” was adopted in the FBiH (“Official Gazette of the Federation of BiH”, No. 7/14) in which there is category of threat in addition to each species listed in the document.<sup>7</sup>

Although the Red Lists are documents that should be based on the same internationally accepted methodology, in reality, in BiH there are two completely

6 Tatjana Ratknic, 2017: ENDAGERED PLANT SPECIES IN SERBIA, Centre for ecology and forestry “Sylva”, available at: <http://sylva.rs/doc/Ugrozene%20biljne%20vrste%20u%20Srbiji.pdf>

7 Protection of endagered species in BiH, blog biolog.ba, 24.05.2017, available at: <http://biolog.ba/58-zastita-ugrozenih-vrsta-u-bih.html>

different documents and it is completely unclear on which parameters the selection and categorization of species was made.

Due to this, it is difficult to identify the real threat for certain animal species primarily those with a specific large radius of daily and seasonal migrations lies. These animals often migrate from one legal entity to another, so the threat assessment is based on a “double record” and is not adequate to the situation on the ground.

On the other hand, technical and organizational protection measures and operational activities on must have their explanation and legal foundation that should be based on a realistic assessment of the threat or insight into the state of the population on the ground. This requires a technical system that provides a permanent insight or at least insight with sufficient frequency, which is only possible by building a system for remote animal tracking and by organizing the systematic and technical protection of endangered species through a certified legal framework.

So-called Red books are Red Lists for a specific geographical region that are put together- these scientific professional publications list all types of organisms that are subject to protection according to the international classification of the level of threat:

- Critically endangered species;
- Endangered species;

- Vulnerable species;
- Rare species.

Rare and endangered species are protected by law in the way that their habitats are declared as strict nature reserves in which a special regime is governed and in which the activity of humans is minimized. Separation of endangered species and provision of habitats within a closed ecosystem represents the most effective way of protecting the species. However, such legal solutions create specific exclusivity and give special rights to park management as well as to special organizations dealing with species protection. Although the legislator's intention is to provide and support the protection of some endangered species in this way, the facts on the ground show that giving wide and particularly exclusive powers is often the source of corruption and the basis for many illegal and even criminal activities. So it is not unusual for the park management to behave as monopolists, using the natural resources as a source for acquiring material and financial profits through trade and / or poaching of the endangered species that they should protect. Measures of technical protection and, in particular, infrastructure for remote control of endangered species of plants and animals, enables the protection and operational measures for protection of endangered species and nature reserves to become transparent and public, and to introduce adequate control of the

protection of endangered species and habitats as such. The fact that certain park managements oppose this is an indirect indicator that clearly shows that the operations are not carried out in an adequate and legally prescribed

manner. On the other hand, the mentioned infrastructure enables wide popularization and raising awareness of the wider community regarding the need to preserve the natural environment and endangered species in it.

### CONSERVATION AND MANAGEMENT OF NATIONAL PARKS

In order to protect endangered species and their habitats today, institutional as well as not institutional measures are applied. Institutional measures are mainly related to the activities of states and governments, while non institutional measures represent all forms of private initiatives to preserve the living world and bio diversity. The United Nations, as an umbrella organization that, among other things deals with the organization of national and international nature conservation initiatives. It has provided a number of recommendations and definitions, as well as standards in the field of conservation of nature and protection of endangered species. The Act on Endangered Species recognizes that fish, wildlife and plants have aesthetic, educational, historical, scientific and recreational values for people and that a person must protect these value, common to all people.<sup>8</sup>

In the past, institutional steps have been taken to protect special nature reserves, within which a number of protected animal species have been provided with protected habitats in such a way that a part of the territory in which that species is inhabited is given

the status of a national park or other nature reserve. Increased demands for the expansion of civilian infrastructure have nevertheless led to increased pressure on these reserves, so there are indirect negative impacts on protected areas. These indirect effects are mostly the consequence of the change in the micro-climate due to changes in the geophysical properties of the adjacent land - the construction of dams and artificial lakes can cause changes in wind blow patterns, change in local humidity and capillary irrigation. The mentioned changes directly affect the ability of an ecosystem to produce food for herbivores and therefore for the predators that feed on them. The construction of thermal power plants or large industrial capacities, a highway or some other main road in the immediate vicinity of the protected reservation has a similar impact. In order to avoid this, there is a legal obligation to develop an impact study. An environmental impact study is often wrong in terms of giving long-term estimates about how the construction of an infrastructure object (civil, utility or energy system) will affect the environment.

<sup>8</sup> Randall Abate, What Can Animal Law Learn from Environmental Law?, Environmental Low Institute, West Academic, 2015 pp 160, ISBN 978-1-58576-176-0



Also, it should be emphasized that due to global climate change, the ecosystem's ability is further reduced in terms of producing the necessary amount of food for a certain number of animals. This leads to a reduction in the number of animals and their extinction unless a person intervenes in critical periods. The intervention primarily involves feeding starved animals through organized feeding facilities without a direct encounter between the rangers and the wild animals.

In order to be successful this type of temporary feeding must correspond with the habits of animals, with their natural migrations and daily needs. That is why adequate and current information provided by the remote animal tracking system is necessary for rangers and especially veterinarians and biologists. In this regard, it is important to note that the conservation and management of national parks can no longer be isolated attempts of park management and their teams to protect them, but the protection in terms of monitoring the conditions must be extended beyond the sphere of protected areas and work on protection projects must be performed in the wider community.<sup>9</sup>

In terms of nature conservation and conservation of individual isolated

ecosystems such as the national parks, modern ICT technology provide multiple advantages compared to classical methods and techniques. ICT technologies offer the following advantages:<sup>10</sup>

- Enable determination of the exact population that settles the habitat within the protected area
- Provide a clear insight into the extent of the territory by individual members and species (one animal's territory, herd territory)
- Show if there are 'surplus' animals that do not have their own territory and which can be transferred to another protected area
- Provide insight into distribution patterns of particular species in a given area, by space and time
- Enable the monitoring and preservation of biodiversity
- Provide quick feedback data

Network infrastructure is the biggest problem with applying new ICT technologies to protected nature reserves. Most ICT technologies are applied in a way that data collection processes are separated from the process of processing and obtaining information, both scientific and operational

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9 Fish and Wildlife Service I&M: Connecting Science-driven Monitoring to Management, National Wildlife Refuge System Inventory and Monitoring (I&M) initiative, Published on 4 Aug 2012, video, 23.12.2016, available at: <https://www.youtube.com/watch?v=XutmC7QRGUM>

10 Priya Joshi, Wildlife conservation through innovative technology: Priya Joshi at TEDxKathmandu, TEDx Talks, Published on 10 Jan 2013, video, 24.12.2016, available at: <https://www.youtube.com/watch?v=bgM5kHZYrO8>

ones in terms of management and popularization. For the former ones, it is necessary to provide a network and / or internet to protected nature reserves, while the latter ones are processed in separate data centers and / or within a cloud solution. It is clear that the most expensive and technically demanding part is equipping the entire protected area with the necessary infrastructure to provide internet access.

In areas where the degree of protection is lower, this is achieved by using standard wi-fi technology with minimal temporary disturbance of the natural habitat during the installation of the cable infrastructure connecting the end nodes and base stations. In the case of bringing the Internet in the areas with higher level of protection, this is done exclusively by the use of wi-fi technologies where the base stations are placed on the periphery of the protected area. In the case of the rainforest, due to the high density of vegetation, the above solutions would not be sufficiently effective. Therefore it is necessary to cover one part of the rainforest with access points used for network devices installed in the animal collars that are monitored from the air. (AP mounted on

drones, balloons or small airships). The fact that Canada is planning to introduce wi-fi in its national parks and thus enable faster and easier data transfer than that one based on mobile technology proves that the idea of installing and using wi-fi technology gets its supporters.<sup>11</sup> Such plans and implemented solutions clearly point to the aim of reducing the operational costs of national parks, while improving and raising the quality of advertising and the provision of distance attendance, for animal lovers and for scientific and educational purposes. It is important to emphasize that without the construction of the appropriate wi-fi network infrastructure there is practically no possibility to apply modern ICT technologies in the field of monitoring and management of nature reserves and protection of endangered species. For adequate data collection, it is necessary to have a network whose transmission latency corresponds to the amount of generated traffic. It is known that IoT devices, especially sensors requiring emulation of continuous monitoring, generate large amounts of data to be transported to the central server on which the data processing will be done and the necessary information will be generated.

### IOT FRAMEWORK

One of the important advantages of the wildlife monitoring system in their

natural habitats using IoT technologies is reflected in the greater transparency

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11 Wi-Fi in the woods: Canada plans to install web hotspots across its national parks and historic sites, Daily Mail, 29 April 2014, On Line izdanje, 24.12.2016, available at: <http://www.dailymail.co.uk/sciencetech/article-2616007/Wi-Fi-woods-Canada-plans-install-web-hotspots-national-parks-historic-sites.html#ixzz4TmNxjQeH>

of the ecosystem process. In that way we can learn how the ecosystem works and not only focus on the salvation of one endangered species, because such a restricted approach often does not give results. If we turn the monitored animal into a kind of a digital product it will create millions of specific measurements<sup>12</sup>, that is, the data needed to create a deeper and better insight into its life, but also the behavior, habits and overall biological needs of the whole species. IoT and BigData solutions allow us to collect and process a large number of data and to create new insights based on it. The best indicator of how advanced this technology is in terms of providing new insights is the fact that it is being increasingly mentioned in scholarly literature.

The reasons why today's development can be described as the Biotelemetry Revolution are:

- Devices are smaller in size and mass, there are a large number of small integrated GPS devices on the market
- Thanks to Cloud technologies, it is possible to collect partial data streams and combine them in order to obtain the most reliable information either in real-time or delayed.

It should be noted that not only does IoT and Big Data provide new scientific insights, but also a new form of resource

management which can be called real-time management based on real information. This kind of management represents a quantitative and qualitative leap from the former management style. Also, the IoT framework is an opportunity to turn ideas into digital products and this raises the question of whether this method can turn a rainforest into a digital product which would be self-sustainable economic model that would protect the rainforest. There is an idea to find new business models to facilitate the operation of protected nature reserves. By converting a national park or protected species into a digital product, it is possible not only to popularize the idea of protection, but it is also possible to obtain additional financial resources to support the work of the nature reserve itself.

ICT helps build both social and infrastructural capacity that is a prerequisite for spreading the awareness of the necessity of protecting endangered animal species, and it does so in the following ways:<sup>13</sup>

- Raising the general level of public awareness of the problems of survival and protection of endangered species
- Provides educational opportunities
- Provides opportunities for professional development of necessary staff to protect endangered species

12 Daniel Smith, 2015 September Webinar IoAHTedited, [TheCSAlliance](https://www.youtube.com/watch?v=DQew3ESgZoQ), University of Cambridge, Cambridge Service Alliance, Published on Sep 15, 2015, video, 23.02.2017, available at: <https://www.youtube.com/watch?v=DQew3ESgZoQ>

13 John Houghton, ICT and the environment in developing countries: opportunities and developments, Centre for Strategic Economic Studies, Victoria University, Australia, *October 2009*,

## ANIMAL INTERNET

One way of transforming protected animals into a digital product is their popularization through the so-called animal Internet and animal social networks. Animal internet represents the level of services directly derived from the IoT solution while the animal social network can be described as a marketing strategy for applying social networking techniques to popularize protected animal species, creating and strengthening links between younger generation and endangered animals and as a marketing and business platform for commercial business activities and raising funds for the preservation of the mentioned species - contributions to the rangers, the nutrition, the necessary infrastructure, the sale of art objects and souvenirs in order to obtain funds.

Some of the techniques used in the application of ICT technologies in real business related to the conservation of protected species are:

- National Geographic has made a website - aggregator - showing images of all the animals to which cameras are attached, and site users see the same things as animals.

- We can use the infrastructure and triggers in such a way that an animal sends a tweet or a message when it catches a prey (for example, the cat catches the

mouse)<sup>14</sup>. In this way, the attention of the audience is maintained, and all “uninteresting frames, that is,” boring “periods when the animal rests and does nothing” are deleted.

- The ability of the user to locate and find an animal at any time and record it (exclusive recording) - thanks to the fact that the necklaces send GPS coordinates,

- Possibility to locate and locate an animal at any time and record it (exclusive recording) - Due to the fact that necklaces send GPS coordinates, the users of the network can position themselves at the same drone coordinates and capture an exclusive recording which is additionally charged.

- Possibility of interactive transmission of wolves or lynx hunting (also using multiple drones allowing interactive transmission)

Also, if the visitors of the national park find themselves in direct contact with large predators, there is the possibility of timely remote notification of the danger. About the possibility of using the Internet as an interface for connecting different biological species, one of the Internet designers Vint Cerf made the following statement: “When the internet was designed, we thought it was a system that connects computers, and it turned out to be the system that

14 Dr Genevieve Bell, The Internet of Beings: Or, What are the Animals Telling Us?, Research Computing Centre, Published on Aug 9, 2016, video, 23.02.2017, available at: <https://www.youtube.com/watch?v=iEosTaPyxOs>

15 Vint Cerf, The interspecies Internet? An idea in progress..., TED, Published on Jul 10, 2013, video, 23.02.2017, available at: <https://www.youtube.com/watch?v=wGMLhaa98GI>

connects people, what we now see is that we should not restrict the network to existing types of connections, but other intelligent types should use the network as well.<sup>15</sup> As more and more tourists are visiting national parks, the likelihood of a casual encounter between tourists and animals within the park increases. More importantly, wild animals in the natural environment often suffer from illnesses that can be transmitted to humans, so it is of great importance to treat the injuries and illnesses of wild animals so they wouldn't spread beyond the boundaries of the national park. Because of this it is crucially important to find

diseased animals as quickly as possible with the non-invasive method and cure them. In such situations it is particularly important to quickly and easily locate the animal and its movement, which is greatly facilitated by the use of GPS modems and wi-fi devices embedded in necklaces and / or bracelets attached to animals (Project Code: 1810, 2017)<sup>16</sup> In this way, a clear insight into the movement of animals is achieved and animals leaving the protected areas and attacking farmers' livestock can be traced. Therefore, it is possible to locate the attackers, to identify their habits and to compensate the damage to farmers.

## ELEMENTS OF THE SYSTEM

### REPETITORS AND AP

Remote monitoring of animals was earlier done by using technologies based on emission techniques in the area of publicly available frequencies and radio devices. This technology is reliable, but rather obsolete because devices are bulky, and a relatively large amount of energy is required to power them. Also, one of the disadvantages of the mentioned technology is that for monitoring purposes it is necessary to build a number of stationary transmitters that are massive and they must be placed on the antenna poles that are at a mutual distance in proportion to the half of the wavelength EMS they use. This technical

requirement often limited the use of radio waves devices in specially protected ecosystems such as rainforests, because placing them in a protected ecosystem would essentially disrupt them which was not allowed by the laws on nature conservation. Due to the massiveness of the transmitter antennas, it was not possible to put them in the air so this was an additional disadvantage in terms of adequate monitoring of wild animals. The emergence of new ICT technologies, primarily wifi technology and then mobile Internet technology has made it possible to overcome these shortcomings, and to make the appropriate non-

16 GPS based Wildlife animal tracking system, Microtronics Technologies, blog, 24.02.2017, available at: <http://www.projectsof8051.com/gps-based-wildlife-animal-tracking-system/>

17 Project Loon : Now Google launches BALLOONS in bid to bring internet to the remotest places on Eart, PatrynWorldLatestNew, Published on Jun 15, 2013, video, 24.02.2017, available at: [https://www.youtube.com/watch?v=\\_0iqX9Lq5B8](https://www.youtube.com/watch?v=_0iqX9Lq5B8)

invasive infrastructure necessary to track wildlife movements. As protected national parks and other nature reserves are located far from urban areas, there are many technical, organizational and economic constraints on the use of ICT technologies, especially in environments such as the jungle. It is difficult to achieve an economically viable Internet infrastructure in remote and inaccessible regions. Google's project Loon secures reliable internet access at high speeds and bandwidths in remote and rural areas in an economically viable way.<sup>17</sup> The project uses high-altitude balloons as repeaters or WiFi AP devices placed in the stratosphere to create an aerial wireless network and it has shown a high level of reliability. The repeater set up so highly allows people and animals to have a signal where they have not previously had it and to connect to the Internet

immediately after major disasters. By using LTE technology and balloons, the speed of 15 MB / s and 40 MB / s can be achieved, depending on the operating range and characteristics of the client's WiFi device.<sup>18</sup> For large areas and wider protected areas Wi-Fi technology becomes inadequate and it has to be replaced with GPS and GSM technology to keep track of animals in the wider area. If the number of transmitters increases in terms of increasing the density, the density of the network used for positioning also increases. For exact spatial positioning, the tag being tracked has to be accessible or connected to at least three APs. Another advantage of wi-fi technology is that the AP can also be positioned in the air, or placed on the drones and / or balloons above the area that should not be disturbed by placing infrastructure elements.

## COLLARS

Another important element of the wildlife monitoring system in their natural environment is the passive tag, that is, the necklace containing the wi-fi device recently integrated with the sensors to monitor the physiology and metabolism of the animal. Larger animals, especially predators, such as lions, bears, lynxes or wolves with ease wear these collars easily and they do not hinder the normal performance of all daily activities. Due to the weight limit, when it comes to birds, this tag

is most often a ring placed on a leg in the form of a passive antenna, enabling tracking of the animal's location, but not the monitoring of some other life functions. All monitoring systems based on placing necklaces or other active markers / sensors on animals have one drawback. They rely on batteries as an energy source, so the necklaces, or batteries, must be changed from time to time in order for the device to work. This problem could be solved by using low power consumption sensors and

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18 Inside Google's wildly ambitious internet balloon project, The Verge, Published on Mar 2, 2015, video, 24.02.2017, available at: <https://www.youtube.com/watch?v=OFGW2sZsUiQ>

modems but even in that case battery consumption is a problem.

For some larger birds, predominantly vultures, it is possible to use a collar with a limited number of sensors while GPS modem is used for locating them. The accuracy of monitoring with this type of collar is defined at a resolution of 500 meters if the base stations are used for goniometry, while it is significantly increased if the goniometry is performed with the moving object (drones for active goniometry) and can be reduced to below 10 meters.<sup>19</sup> The 3D position is usually obtained by interpolation between measuring points obtained by direct measurement.<sup>20</sup> This is due to the fact that most land animals fairly move in the vertical plane - rare, mostly periodic seasonal migrations.

Tracking devices (collars) can be sorted according to the following characteristics:

- The type of device and technology used
- Energy budget and operating autonomy
- Device size
- Number of sensors integrated in the device and their accuracy
- Data rate and network throughput

- Adaptability of the device to animal behavior

- Attaching method and location

Modern tracking systems must support 2D and 3D modes of wildlife monitoring. The 3D monitoring mode is especially interesting for birds, fish, large mammals living in the sea or lake waters, animals living in tree canopy, animals with periodic migration from north to south, or vertical migrations to more and lower regions.

Some of the areas where collar technology is applied today are:<sup>21</sup>

- Identification of an individual animal in a group
- Tracking the animal and its movement, as well as social behavior
- Monitoring of animal health
- Communication between animals and humans and between animals and things (eg feeder, water troughs, etc.)
- Behavior regulatory mechanisms (various types of speakers that are carried on the collar and can be remotely activated whenever an animal enters forbidden area)

Since the autonomy of the device depends on the number of logs that the device will send to a server in the unit of

19 M.K.Nor, M.S. Masbop, Smart Livestock Tracker, The International Journal of Engineering And Science (IJES), 2015, Volume 4, Issue 7, PP 25-29, ISBN (e): 2319-1813, ISSN (p): 2319-1805

20 Dr Robert Sinkovits: Improving Wildlife Tracking via HPC, Research Computing Centre, Published on 7 Dec 2015, video, 23.12.2016, available at: <https://www.youtube.com/watch?v=uubLZwIuEjU>

21 Lena M Holmberg, Internet of Animals, 05.07.2016, blog, 03.03.2017, available at: <http://lenamholmberg.blogspot.ba/2016/05/internet-of-animals.html>

time, an acceptable flow time is required for each type of monitored animal. This flow time depends on the species and gender, but also the lifestyle and behavior of the individual. For example, tagged fish can be tracked for up to two years after setting up a tracking devices. The energy budget must enable at least half of the annual cycle - the collars must not be changed during the mating season due to the aggressiveness of the

males. Also, cubs must not be equipped with collars until they reach full maturity due to intense growth. Once the battery dies the whole collar should be changed because it has to stay impermeable so that the sensor system and antenna can work. Most collars are made in so-called vandal proof housings in a part related to antenna, power supply and sensor storage (IP67 standard).

## DRONES

The problem of covering the territory, namely, monitoring the population with a minimum number of static and dynamic sensor systems is resolved by an optimal combination of static devices and dynamically robotized autonomous systems (often called drones) for data collection. The optimum number of drones for the highly popular digital web platform, that is, the extremely popular social group of animals, can be estimated at about half of the population, meaning that one dron can adequately monitor more members of species, especially those species that gather in packs and herds.

A large number of drones in such scenarios are used for individual monitoring of single males, who may be expected to attack dominant males and attempt to secure their position and entitlement to females. In this way not too much time is spent on unattractive content when animals rest and do nothing that would keep the audience particularly entertained. In addition to

being used for monitoring, recording and controlling individual animals, drones are also used in national parks to control the periphery, prevent curls and/or cutting of forest in a protected area. In this way, drones become an essential tool for improving the work of the ranger service, but also for controlling their work, as they enable the global insight of the public into events and possible illegal activities within national parks. Drones are also used to collect data on distributed systems such as flocks of fish or mosquitos or other flying insects and birds. The use of autonomous robots allows a much wider image than the static devices because, besides the geometric data (position, distribution, trajectory), it also provides a number of semantic information such as the number of defective fruits (apples) on the tree.<sup>22</sup>

The first task of automated robotic systems for the monitoring of wild animals in nature is to find or, to detect the signal from the necklace, ie, the



tag. This task in terms of dispersedly distributed systems such as flocks or bird flies can be performed with automatic search algorithms: a dron travels over some surface and searches for the signals which then are processed (counts, collects data after initiating communication, etc.), then it sends to some cloud location where business logic and mapping software, that gives GIS data through a map of a terrain are located.

Covering the territory with autonomous robots is done using the following search techniques:

- Stationary coverage search model
- Stochastic model - the random movement of the drones that collect data
- Contradictory - cross-collecting data with the following two game theory models:
  - o Active avoidance of the meeting
  - o Avoidance game (cat and mouse game)

LiDAR cameras are often used as active devices for capturing the state of the drones. Their resolution is large enough to map all recorded elements of the ecosystem, giving real 3D views

of the current state of the system, that is, allowing real movement through the elements of the system in all directions. The advantages of using drones in terms of protecting national parks, as well as insights into the life and behavior of wild animals compared to other technologies are reflected in:<sup>23</sup>

- Cheap technology (compared to airplanes, and a large on-site patrol service)
- Easy to use
- Available for use (standard technology that is rapidly evolving)
- Multifunctional platform - can be used for tracking animals, collecting data from collars and sensors attached to animals, capturing nature and animals in nature, tracking people (tourists, lost people, searching for and preventing the activity of hunters and those who try illegal logging), early detection and localization of the fire, notification of the closest patrol of the rangers, supporting field operations, support for quick responses

Additional advantages of using drones can be counted as follows:<sup>24</sup>

- Easy location of fairly hard-to-spot animals (Orangutans, Gorillas,

22 Ibrahim Volkan Isler, Associate Professor, University of Minnesota, RI Seminar: Ibrahim Volkan Isler: Robotic Data Gathering in the Wild, November 04, 2016, video, 23.12.2016, available at: <https://www.youtube.com/watch?v=tcTUv0wW7J8>

23 Wildlife conservation with the help of drones: Kitso Epema at TEDxUtrecht, TEDx Talks, Published on 28 Apr 2014, video, 23.12.2016, available at: <https://www.youtube.com/watch?v=LT9q6kra90c>

24 Using drones to conserve natural habitats | Professor Serge Wich | TEDxLiverpool, TEDx Talks, Published on 20 Aug 2014, video, 23.12.2016, available at: <https://www.youtube.com/watch?v=GTsMi43Mugo>

Chimpanzees in tropical forests) - thanks to drones it is easy to detect and track migrations

- Ai technologies (automatic optical recognition) increase the probability of recognizing settlement in tree canopies

- Drones can be used in the “data mule” scenario, where they collect data from sensors and cameras (static) to free memory for future work, emptying data loggers. Due to the low flying potential, communication is possible in the near field, so less energy is used for communication and there is the possibility of uploading large files (HD cameras)

- Compared to conventional manual animal data collection, drones are up to 200 times more effective than humans (it takes about 20 minutes for drone to locate animals and collect data from monitoring devices while biologists and the rangers need up to 3 days for the same task (using hunting tracking techniques)

- Drones can fly low enough and give images of large resolutions, as well as record in infrared

- They can be made as DIY project

- Due to the high cost-savings based on their high efficiency, it is possible to reallocate budget resources and purchase additional equipment (other types of hardware and software that can be used on drone platforms)

Legal restrictions on the use of automatic robotic systems and handheld

drones

Although drones are perhaps the most efficient platforms for monitoring the lives of wildlife in their natural environment and therefore extremely interesting technical solutions, their usage is hampered by the fact that the drones are a new legal area in which there are no clear regulations

and the legislators are late with the legal framework for their use. A particular problem of the use of drones for this purpose is the fact that drones are usually not produced in the countries of use and that for their production there are no clear quality standards that producers and importers should adhere to. Since drones belong to aircraft, in most countries, they are subject to special regulatory commissions and air traffic control (if the flight exceeds a certain threshold defined by local laws) and the flight is carried out beyond the limited airport areas. A special problem is also the fact that drones are most commonly used for aerial scouting with mounted cameras that can be misused for unauthorized surveillance, monitoring and even for the purpose of voyaging, which all falls under special laws that are not extended in most of the countries even to this new legal domain.

Considering legal, moral and other limitations of the use of the drones, we must ask and resolve the following questions:<sup>25</sup>

- Who regulates the rights to use the

25 Best and worst states when it comes to drone laws, Drone U, Published on 6 Sep 2016, video, 24.12.2016, available at: <https://www.youtube.com/watch?v=p7DEAXLXeZY>

aircraft and in what way?

- How to get a drone license? Who issues a license or this area hasn't been regulated yet?

- Who is responsible for the fall of the aircraft? Especially if, with its fall, it causes material damage and / or endangers human lives?

- Are there legal procedures for the maintenance of the aircraft? Are there any certifications and what kind of experts issue them to both aircraft and those who maintain them?

- Should a drone have its own logbook and how it is being kept?

- In the case of a DIY drone, who issues an operating license? How to control the quality of production and whether the safety standards are met?

- How are the drones with instruments in the visible spectrum regulated, regarding the privacy of those that can be covered with recorded material?

- What is the minimum flight altitude - prescribed by the air traffic control agency?

- Does any state authority - the agency you are addressing, have the competencies to answer your questions regarding the regulations governing the use of drones?

What is particularly important to emphasize is the fact that although drones are an ideal platform for application in the field of monitoring wild animals in their natural habitats, certain countries

legally prohibit their use in national parks, for example Mexico.

In some US states, this ban has been expanded due to possible voyeurism and / or drug trafficking across the border, and the use of this technology in border areas can lead to up to 5 years in prison.

Even in cases where certain areas of application of drones are regulated, there is a lawful possibility of a lawsuit, but in that case, one who complains about a breach of privacy must prove that there was an intention to abuse this technology in order to violate the complainant's privacy. Counterargument in such a legal battle is certainly a reference to a reasonable expectation of privacy with regard to modern technologies that have similar possibilities of insight into someone's privacy. This is particularly interesting since the hunters and tourists who have violated some of the rules of the national park (burning fire, throwing garbage, damaging the crop etc) are most often the ones who complain about the violation of privacy, so for the purpose of applying drones as a means of protecting the natural environment for wildlife it is necessary to have the appropriate clear legal regulation to clearly and unambiguously regulate this area.

## SERVER INFRASTRUCTURE AND SOFTWARE

The next significant part of the infrastructure is the server and storage infrastructure that can be implemented as a cloud solution, which means that it does not have to be directly connected to the location. The benefits of such performance are primarily reflected in the ability to provide an adequate infrastructure that would, depending on the access rights and capabilities of the client software, give the various interested parties exact information and data they need. Also it would separate obtained data in those that would be used for marketing presentation of animals in order to create a critical mass of the on-line followers and provide funding for a national park or other form of organization in the

protected territory and necessary data for biologists, veterinarians and analysts to make adequate analysis and scientific and expert studies of animal behavior. The hardware infrastructure elements of the data center include: Server, Storage devices, firewall, DRC, or the following virtual infrastructure: VM-web server, VM-RBDMS, VM-image, FTP, VM-AVServer, VM-AppServer, VM-InteroperabilitySystem, VM-ImageSocialNetwork. All of the above hardware and software infrastructure can be implemented as a service that is rented for a certain period, so in this way it is possible to facilitate the financing of animal tracking projects, whether they are of the commercial nature or part of a scientific research.

## DATA COLLECTION

The ability to collect and process credible information on various aspects of the environment enables quality control and management, both of natural resources and of external influences that can endanger the environment.<sup>26</sup> With good selection of data collection technology we can collect data in a minimally invasive way regarding interference in the ecosystem, so the risks related to environmental security related to data collection can be minimized. Data collection can take

place at two separate levels: at the data level of the animal itself, monitoring and recording data - animal status indicators and at ecosystem level, monitoring and reporting environmental parameters taken from a wider ecosystem. ICT systems implemented in a proactive way ensure the sustainability and protection of the ecosystem as a whole, and not just of individual biological species. It is also important to note the following facts. Without the use of IoT technology in practice, veterinarians base their

<sup>26</sup> Mira Mileusnić Škrtić, Karolina Horvatiničić, Dragutin Vuković, Risks and opportunities for applying new technologies in terms of environmental protection and sustainability - from the aspect of ICT application, , scientific symposium DEVELOPMENT AND ENVIRONMENT - PERSPECTIVE OF SUSTAINABILITY , 2011, available at: [https://bib.irb.hr/datoteka/550944.Rizici\\_i\\_mogucnosti\\_primjene\\_novih\\_tehnologija.pdf](https://bib.irb.hr/datoteka/550944.Rizici_i_mogucnosti_primjene_novih_tehnologija.pdf)

patient knowledge and their concerns on short consultations with rangers and biologists who have observed unusual behavior of the animal.<sup>27</sup> Most of the national parks take care of their animal and protected species in this way, because so far it has been the usual form of animal monitoring and management. Since this is a very unreliable way of monitoring health, the development of integrated cloud based solutions over the collected data is directed towards finding algorithms that would create a matrix of behavior patterns for each individual animal and compare it with the current behavior of the animal, and on the basis of it, determine whether the animal behaves in the limits of the usual behavior or beyond those boundaries. In case of unusual behavior mechanisms for additional monitoring and veterinary team would be included. It is important to state out that for most wild animals, there is no clear reference range for biological indicators because enough measurements, that could be a reliable predictor of future animal behavior and assessment of its health status, have never been performed.<sup>28</sup> This circumstance leads to reduced accuracy in prediction of animal behavior, but also the necessity to reach this data as quickly as possible, so besides the classic

BigData model, application of machine learning algorithms and artificial intelligence is very likely. Also, these data collection technologies have great advantages when assessing the load of an isolated ecosystem with the number of members of a certain species. Today forestry farms are most often managed on the basis of data representing the population's estimation of a species.

For example, for predators, it is necessary to estimate the number at least 3 times a year depending on the change of seasons and the period of mating and raising the young. the following data is taken as the methods for assessment: directly collected, indirectly collected, re-capture and counting of animals and estimation of population density based on presumed social behavior of animals using statistical methods.<sup>29</sup> In this way, accurate data are often not obtained, and abusive calculations of both large and capital prey are also possible. The population counting and statistical methods in the future will be replaced with systems for direct monitoring of wild animals, which at the same time will become a media platform for spreading awareness about the need to preserve the species. By collecting real-time data from the field, it is possible to make well-

27 Anne Accardi, How the Internet of Things is Impacting Animal Health Part 2: Companion Animals, 11.09.2017, Engage Mobile, 03.03.2017, dostupno na mreži: <http://www.engagemobile.com/how-the-internet-of-things-is-impacting-animal-health-part-2-companion-animals/>

28 Dr Elisabetta Canali, ANIMAL WELFARE ASSESSMENT THROUGH SMARTPHONE APPLICATIONS: CHALLENGES AND OPPORTUNITIES, [OIEVideo](#), Published on Dec 7, 2016, video, 02.03.2017, available at: <https://www.youtube.com/watch?v=FK1vcB-G9nk>

29 ESTIMATING WILDLIFE POPULATIONS, FW (ZO) 353, Wildlife Management, 02.03.2017, available at: <https://projects.ncsu.edu/cals/course/fw353/Estimate.htm>

based and informed decisions regarding the maintenance of ecosystems within the limits of biological capabilities and

anticipate adequate scenarios for critical situations.

## CONCLUSION

From all of this, it is evident that modern ICT technologies represent not only a technological basis for collecting data for scientific and professional wildlife behavior studies, but also a very useful basis for monitoring and managing real operations within national parks. An implementation of these technologies in order to achieve educational, scientific and commercial goals, and in the long term, allow the additional financing of parks and all

operations related to the protection of animals is a priority in the near future. This is even more important given the fact that the above-mentioned business model based on the business model of the animal internet and endangered species itself involves the provision of financial resources necessary for protection, thereby reducing the burden on the budget and the processes of wildlife protection becoming transparent and self-sustainable.

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Paper received: 18.6.2017.

Paper accepted: 18.4.2018.