IOSR Journal of Computer Engineering (IOSR-JCE)
e-ISSN: 2278-0661,p-ISSN: 2278-8727, Volume 17, Issue 5, Ver. I (Sep. – Oct. 2015), PP 39-45
www.iosrjournals.org

MannAnuro: Classification and Identification of Anuran Amphibians using Wireless Multimedia Sensor Network

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Abstract: *This paper evaluates the energy consumption between two approaches that use Wireless Multimedia Sensor Network (WMSN) for classification of amphibians species. The classification on the first approach is made in each of the node sensors, proposal advocated in this paper, while the second, classification is made in sink, traditional approach to literature. Recent studies show that in a WMSN, reducing energy consumption is a major challenge. Both approaches were applied in two experiments using the Castalia simulator. The data analysis showed a significant difference between the two approaches, identifying that the first approach overcomes the second in energy efficiency. Considering the scenario of 25 sensor nodes, one sink node and the 30-second transmission rate, the first approach was 13% more efficient in energy consumption compared to the second. Thus, the first approach significantly increases the network uptime.*
Keywords: *Anuran, Environmental, Multimedia, Sensor.*

I. Introduction

The monitoring of habitats and species of animal or vegetable has presented a research field with great potential benefits for the scientific community and society in general [1]. Through the sounds of animals you can get information on the degradation of a particular environmental area. In particular, the frogs are being used by biologists as an indicator of environmental stress. Speech recognition techniques in human have been adapted for the recognition of species of animals. Time-frequency representations such as the Fast Fourier Transform (FFT) spectrum, spectrogram, Wigner-Ville Distribution (WVD), Mel-frequency cepstrum coefficients and wavelets, are often used as tool to solve the automatic identification of species problem [2]. One way to monitor these animals is through the use of Wireless Sensor Networks (WSN).

The most common applications of WSN are formed by sensor devices such as temperature, light, humidity and pressure. The difficulties associated with the development of applications for WSNs that collect such parameters are related to the large number of sensor nodes, hundreds to thousands, and the restrictive features of WSNs - restrictions associated with hardware capacity, energy storage and recharge [3][4]. When a WSN includes audio and image sensing devices it is called Wireless Multimedia Sensor Network (WMSN). These networks are capable to collect audio and video streams, and can also include scalar sensors, such as temperature, humidity and light [5].

The WMSN inherits the traditional problems of WSN, such as location, address and limited resources, and deals with the challenges and the need for requirements as demand for bandwidth, coding techniques, requirements for service quality and information quality. In the case of the development of applications for WMSN it is interesting to organize the solution according to the availability of services, such as sensing service, processing service and communication service. In particular, coding techniques should be defined considering the device resources such as memory, transmission rate, battery and processing, in order to reduce the amount of multimedia data to be transmitted by the sensor nodes.

This work deals with this challenge: proposing a WMSN for anuran amphibians monitoring. One of the contributions of the work was the development of an acoustic node prototype based on the Waspmote platform. The challenges overcome are related to the study of the best solution in energy cost and benefit in terms of data acquisition. Several experiments were carried out in terms of information gathering and audio quality to achieve the mounting of the most suitable network element. From the defined solution for the sensing service, a second phase began considering the processing service. The contributions in this phase are related to the identification of problems in the classification and identification of species. Some algorithms were studied through implementation and testing until an efficient solution to the processing service was defined. Considering the communication service, one of the contributions of the work was to promote the reduction of the amount of transmitted data by adopting a mapping strategy in the processing phase. For the communication service Zigbee protocol was used.

Besides this introduction, this paper is organized as follows: section 2 presents the related work to the species classification of anuran amphibians by their vocalization and monitoring of the environment through animals; section 3 presents an overview of WMSN and explains the process used for the classification and identification of amphibians species; section 4 describes the experiments and results; section 5 describes the simulations and section 6 presents the conclusions.

II. Related Work

Although the work of [6] did not use any type of WSNs, it is important to highlight the use of Mel-Frequency Cepstral Coefficients (MFCCs) in tracking minke whales. In this work, the sound of whales was collected by seven hydrophones, about 4 or 5 meters deep, 45 kilometers northwest of Kauai and were extracted 13 MFCCs with 65 dimensionalities. This representation is best for acoustic events with high Signal-to-Noise-Ratio (SNR) [7]. In the work presented by [8] it was developed a system for classification of anuran based on their vocalization. This system divides the sound emitted by the anuran in syllables, extracts some features, performs processing and makes the classification of sound. The extraction activity of the characteristics of each syllable is based on the calculation of MFCC, Spectral Centroid, Signal Bandwidth and Zero-Crossing Rate, which will later be used in the classification process. In the process of classification, k-Nearest Neighbor (kNN) and Support Vector Machine (SVM) algorithms were used to identify the species of anuran, reaching an accuracy rate of 98.97%. The authors claim that the system has improved the accuracy rate of 16.09% in relation to the work presented by [9]. In addition, the authors used a WSN to collect audio from animals, but they did not describe the settings and/or characteristics of the devices used for the construction of this network. This work differs from what it is being proposed in this article regarding the location of the implementation of the classification algorithm. The algorithm developed by [8] for the classification of species is executed at the base station (sink) and the algorithm proposed in this paper is executed in the sensor node, which is a big challenge because the sensor nodes have few computational resources.

The authors [10] present an IP Core, in developmental stage, for the classification of sounds using WSN. In this paper, the authors use a sound classification process similar to that shown by [8]. The input signal was extracted from a database provided by the University of Montana formed by sounds of twenty bird species, the signal characteristics are extracted using MFCC calculation and for the signal classification and identification the algorithms kNN, Tree J48 and SVM were analyzed. Based on tests conducted in Matlab, SVM and kNN algorithms showed better results, reaching approximately 98% correct in the two algorithms. Although both algorithms provided similar results, the kNN algorithm has a disadvantage for real time applications. Therefore, the authors decided to use the SVM algorithm and as future work, the authors intend to use VHSIC Hardware Description Language (VHDL) and Field Programmable Gate Array (FPGA) for the implementation of this algorithm.

The work of [11] presents the development of a prototype acoustic sensor node for monitoring and classification of amphibian anurans called Mana-M. Mana-M consists of a 32-Bit Atmel AVR UC3B microcontroller, with a frequency of 66 MHz, 256 KB Flash, 32 KB SRAM memory, DMA controller and 10-bit ADC, and a MicaZ mote with MTS310CA sensor board. The classification algorithm is implemented in the Atmel microcontroller and after the identification of the anuran species, it uses MicaZ sensor node to send a signal to the base station (sink), advising that a species of anuran was found. This work identifies only one species of anuran amphibian, furthermore, two microcontrollers (Atmel AVR32-UC3B and MicaZ) are used, which inevitably increases the energy consumption of the network.

The work of [12] implements a WSN for monitoring of animal sounds without considering the frequency rate and without implementing the species classification. A protocol was set using a MicaZ with ATmega 128L processor of 7.3728 MHz, 128 KB of program memory (flash), 4 KB of data memory (SRAM), one radio module (CC2420) with a transmission rate of 250 kbps and a sensor board (MTS300) to capture the sound. In this network it was also implemented the Differential Pulse Code Modulation (DPCM) algorithm for data compressing, which showed a reduction of the time of data transmission as well as power consumption. However, this reduction of time transmission could be associated with the environment where the network was applied. The paper also does not use many sensor nodes and does not present a process for classification and identification of species of animals.

A system for recognition of anuran species was developed by [13]. The system allows performing consult online, but it does not use WMSN. The users need upload the recorded audio signals to system. The sampled signals are converted into frequency signals. Then syllable segmentation and feature selection methods are employed to separate the original anuran calls into syllables and to derive the input feature sets for the classifiers. Six features, including spectral centroid, signal bandwidth, spectral roll-off, threshold-crossing rate, spectral flatness, and average energy, are extracted and served as the input parameters of the classifier. Experimental results show that the recognition rate of the proposed identification system can reach up to 93.4%.

In [14], they propose a classification method of animal species based on their sound signal. The proposed method uses entropy of the sound signal as feature for represent the animal species. Entropy is a measure of information contents or complexity for a sequence of a signal. The frog sound classification method basically consists of three processes: syllable segmentation, feature extraction and classification. The segmentation process divides the frog call into syllables. After the segmentation, three features are extracted from the sound syllables namely Shannon entropy, Rényi entropy and Tsallis entropy. The classification process uses kNN classifier. Nine frog species were used in the evaluation. The frog sound signal were obtained from Frog Australia Network database. In general, the method correctly identified 100% the samples, only two species failed because they are associated to the resemblance between the entropy values of these species.

MannAnuro extends all the functionality of the jobs presented, since the solution proposed includes the classification and identification of species of anuran amphibians. Furthermore, the classification algorithm developed is implemented in the sensor node, and transmits only one code previously configured, related to the kind encountered, rather than transmitting the collected audio signal in order to reduce the energy consumption in transmission of the audio signal to the node sink.

III. Mannanuro: process to classify and identify species of anuran amphibians using wmsn

WMSN is defined by [5] as a network constituted of wireless sensors nodes equipped with multimedia devices, such as cameras CMOS and microphones that enable audio, image and video collection of environment. As mentioned, the services of a WMSN can be organized in sensing, processing and communication. This organization does not separate the functionality of the network, but it is useful to define the strategies and solutions according to the requisitions of Quality of Service (QoS) and Quality of Information (QoI).

The application of WMSN developed considers the monitoring of anuran amphibians. The anurans are considered as environmental bioindicators and they are highly sensitive, so to the smallest imbalance in their habitat they reduce reproductive capacity, which can lead to the rapid disappearance of their species. The environmental degradation can occur by deforestation of environmental reserves, pollution of air, water and soil. These types of degradation can be easily identified through the use of gas, temperature and humidity sensors. However, the imbalance in the food chain may be considered as a form of environmental degradation and the identification of increase or reduction of an anuran species can indicate an environmental imbalance. The reduction of a particular animal species of a region can occur by the appearance of new predators or by the reduction or absence of food. Identify this form of environmental degradation is not trivial, so it is necessary to use other types of sensors, for example, audio and camera (image / video) sensors. However, the use of these sensors requires more computational resources and consequently, they consume more energy, which is a major challenge for the area WMSN.

A. Sensing Service

As proof of concept, a sensor node prototype was developed based on Waspmote platform. Waspmote is a hardware platform for WSN designed by Libelium to be efficient in energy consumption. The platform Waspmote used in this work has an ATmega 1281of 8MZ microcontroller, 8 KB of SRAM, 128 KB program memory, 4 KB of EEPROM.

To define the most appropriate solution in terms of QoI, namely better sample gathering, studies were conducted with different microphones until the results pointed to the use of an electret microphone because of the low power consumption. It was added to the Waspmote platform an electret microphone to capture the audio signal and also, to amplify the signal from the microphone.

B. Processing Service

The sampling frequency used for the sound reconstruction with high fidelity is 44.1 kHz, following the Nyquist rule. The high sampling frequency produces a large amount of data, which leads to the need for high bandwidth for data transmission [15]. It is impractical to use high sampling frequency for WMSN due to high power consumption for the collection and processing of data. Furthermore, the algorithm for classification and identification of anuran species is implemented on the sensor node and due to the memory restriction of these devices, it is only possible to store a portion of the acoustic signal. Therefore, the reduction of the sampling frequency is required.

In this work, the sampling frequency of 8 kHz was used, 128 samples of acoustic signal were used in the process of classification and identification of anuran species. This process is separated into two phases: the training and the classification (Fig. 1). The acoustic signal collected by the sensor node is used in both phases, but the sign used in the classification phase is different from that one used in the training phase. In the training phase, the acoustic signal is used by data classification algorithm to extract a pattern of anuran vocalization and in the classification phase, the acoustic signal is used to perform the comparison with the pattern found in the training phase.

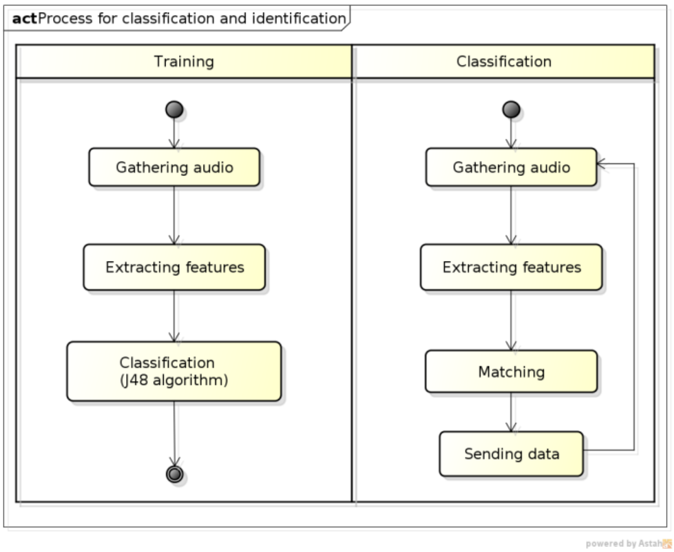

Figure 1. Process of classification and identification of anuran amphibians.

The training phase is organized into activities which are:

- Audio gathering using MannAnuro, adapted sensor node that includes an electret microphone that is able to collect the vocalization of the anuran amphibian;
- Extracting features from the audio signal using the Fast Fourier Transform. A feature vector is the result of this activity;
- Classification using J48 algorithm, a model of decision tree is generated from the analysis of the characteristics of the training audio signal;
- Decision model is used in the classification phase to identify the species of anuran.

The first two activities of the classification phase are equal to the training phase, the remaining activities of the classification phase are:

- Matching, after the training phase, the feature vector is used in the matching activity, where the model generated in the training phase is used to identify the species of anuran;
- Sending data to the sink node. Only the code of specie found is sent to the sink node by using the ZigBee protocol.

C. Communication Service

The communication service uses the ZigBee protocol, which is a specification of the ZigBee Alliance to provide wireless communication based on the 802.15.4 standard. The ZigBee Alliance is an association of manufacturers of wireless technology, working together to manufacture products of reliable monitoring and control, low cost and low power consumption based on a global standard.

Recent technologies of sensor nodes, for instance, the motes of CrossBow and Libelium, have been adopting the ZigBee standard to obtain longer life time for applications. This pattern uses the medium access control CSMA-CA, achieving a maximum transmission rate of 250 Kbps. This limitation on the transmission rate is big challenge to the application development for WMSN, but as the communication service implemented in this work does not transmit the audio stream on the network, it only sends a code of species found, this protocol is suitable for use.

IV. Experiments

Experiments were performed in the Manna-x laboratory of the State University of Maringá considering each of the three services, which are: sensing, processing and communication. Despite the broad context defined for the WMSN solution that monitors anuran amphibians, in this work the experiments were conducted to evaluate the solution proposed to the network elements, network traffic, and the species classification and identification algorithm. It was used three MicaZ nodes to monitor the environment, in other words, collect data on temperature and humidity, and three MannAnuros nodes were developed from the Waspmote platform to monitor the acoustic signal. The audio of the anuran vocalization was obtained from the Interactive Guide of Anuran Amphibians of the Atlantic and recorded on an mp3 player to reproduce the croaking of the anuran. The sounds used in the experiment were from the anuran species Allobates Femoralis and Aplastodiscus Perviridis.

The process of classification and identification of anuran amphibians starts with the training phase of the classification algorithm, which has the objective of building a model that is able to automatically classify species of amphibians from their characteristics. At this phase it was collected 1000 samples of each species vocalization with the use of a WMSN implemented, and it was extracted the characteristics from each sample with RADIX-4 FFT algorithm. The Weka tool was used to perform the training phase, in this work it was chosen J48 algorithm which is based on decision tree, it is easy to implement and uses little computational resource. The Weka tool was developed in Java, its source code is open on the GNU General Public Licence and has several machine learning algorithms implemented for data mining. After the training phase it was obtained a (pattern) model that was implemented and installed in the Waspmote sensor node.

In the classification phase new samples of vocalization of anurans are collected and for each sample it is extracted features and compared with the model generated in the training phase. In the implementation of the classification algorithm it was defined a code for each species (Allobates Femoralis and Aplastodiscus Perviridis) and when a species is identified, only the code will be sent to the sink node. The anuran sounds were played 200 times for each species, obtaining 97.3% of the samples correctly identified.

V. Simulation

The MannAnuro algorithm makes the classification and identification of anuran amphibians and transmits only a code (1 byte) at the sink node, it is not necessary to transmit acoustic signal sample (128 bytes). To evaluate the performance of the network in relation to packet loss, packets received, and energy consumption, it was defined two scenarios: (1) the first scenario consists of two nodes, one sink node and one sensor node, and the distance between the two nodes is 50 meters, (2) in the second scenario was defined a region of 10,000 m² (100x100), consisting of 26 nodes, with 25 sensor nodes in grid (5x5) and the sink node in the center. The energy of sensor nodes is set to 18720 Joules, which is equivalent to two AA batteries. For each scenario it was considered two applications, one that transmits the audio sample collected (app) and another that uses the MannAnuro algorithm (MannAnuro) and only transmits the identification code of the species, and also it was evaluated two ranges of data transmission by sensor nodes, 30 and 60 seconds.

The energy cost to transmit 1 Kb at a distance of 100 meters is approximately 1 Joule. Therefore, the power consumption to transmit one byte at a distance of 50 meters is 0.001464844 Joule and to transmit 128 bytes at the same distance is 0.1875 Joule. The scenarios were executed in Castalia WSN simulator and simulation time for each scenario was set at 200,000 seconds, repeated 33 times.

A. Results obtained with the simulation of the first scenario

The MannAnuro application obtained better results in comparison with the application that transmits the acoustic signal sample (app), in relation to packets transmitted, packets received and energy saving. The amount of packets transmitted by the two applications is shown in Fig. 2, it can be seen that MannAnuro application reaches 10% more transmit packets, considering the interval of 30 seconds of the transmission. The amount of packets received by the applications can be visualized in Fig. 3. In the interval of 30 seconds, the MannAnuro application receives 170% more packets than the other application (app), because this application sends a small data packet on the network, providing then fewer failures in the transmission of packets.

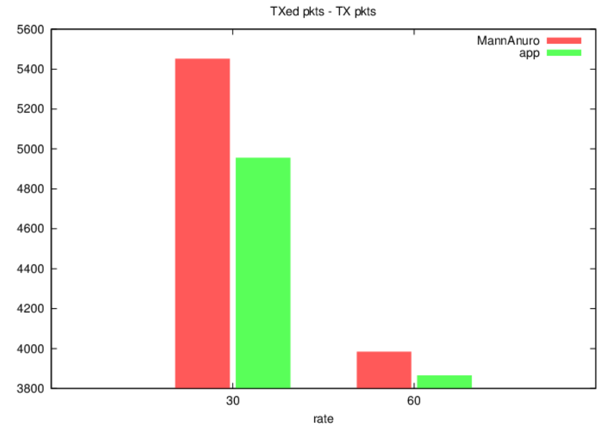

Figure 2. Packets sent by the applications.

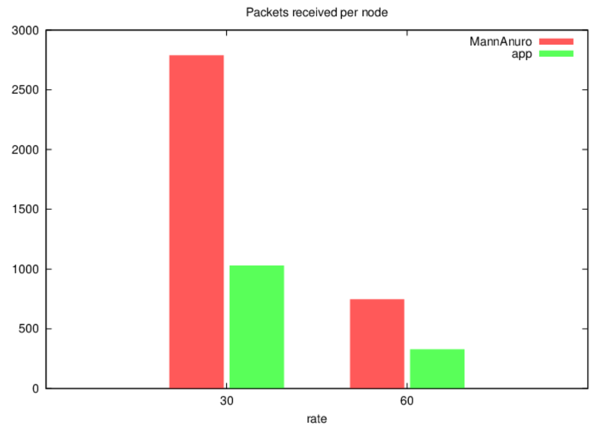

Figure 3. Packets received by applications.

Figure 4 shows the power consumption of the network considering the two intervals of data transmission and two applications. The MannAnuro application was 5% more economical in transmission interval of 30 seconds and 2.5% in the interval of 60 seconds.

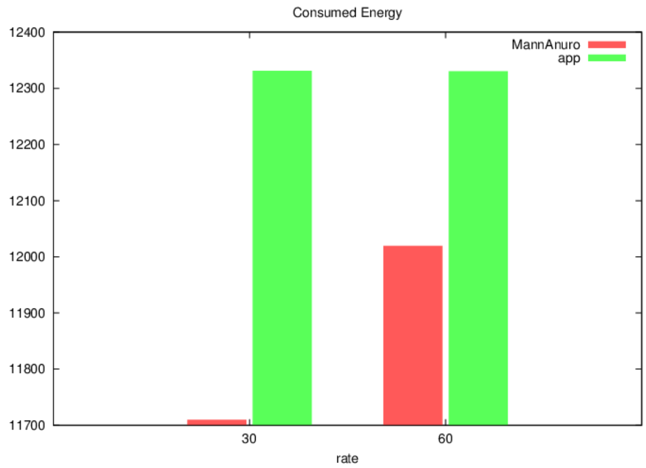

Figure 4. Energy consumed by the sensor nodes.

B. Results obtained by simulating the second scenario

This scenario was defined with 25 sensor nodes (5x5) and one sink node, and applications were also evaluated in relation to packets transmitted, packets received and energy saving. The results obtained show that the MannAnuro application is more efficient than the application (app).

Figure 5 shows the amount of packets transmitted by each application and Fig. 6 shows the amount of packets received by each application, considering the two intervals of transmission of packets.

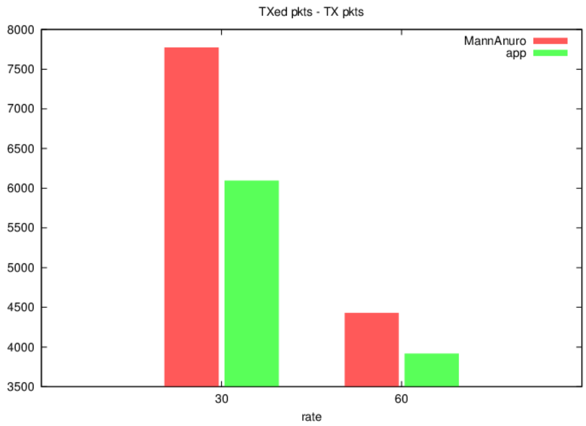

Figure 5. Packets sent by the applications.

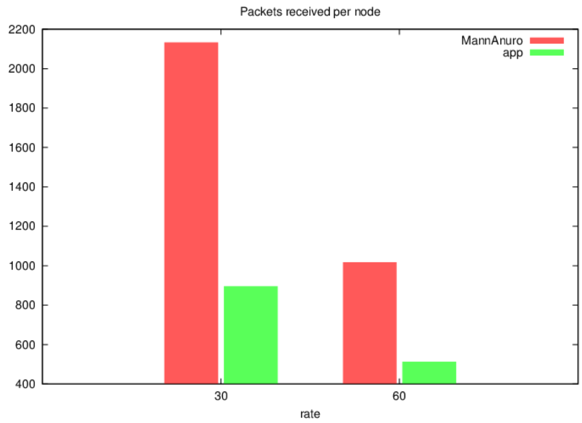

Figure 6. Packets received by applications.

The MannAnuro application obtained better results considering the amount of packets transmitted and amount of packets received. In transmission interval of 30 seconds, the MannAnuro application sends 21% more packets and receives 98% more packets than the application (app).

Figure 7 shows the energy consumed by the sensor nodes of each application. It can be observed in this figure that the MannAnuro application was 13% more economical in energy, considering the interval of 30 seconds, and 8% more economical considering the interval of 60 seconds.

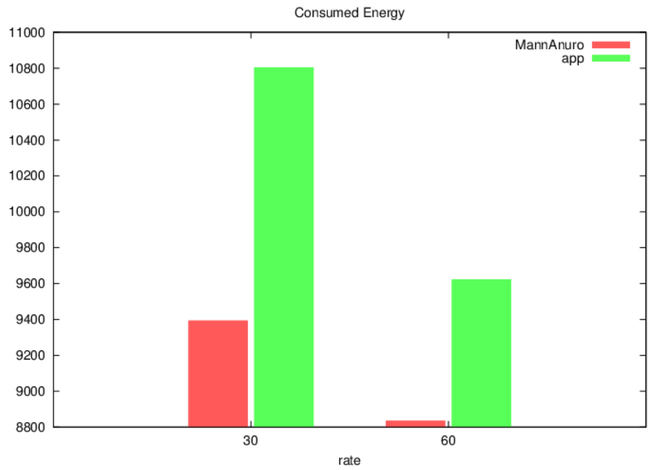

Figure 7. Energy consumed by the sensor nodes.

VI. Conclusions and Future Work

This paper presented a solution, energy efficient, for classification and identification of amphibian species using WMSN. The solution consists of a commercial sensor node adapted to collect audio and an algorithm for classification of amphibian species. The algorithm developed obtained 97.3% of samples correctly identified and presents an approach of classification different from those found in the literature. This approach reduces the energy consumption of sensor nodes of the network because the size of the packets transmitted on the network is small. This work deals with the challenges of power consumption, bandwidth, memory and processing constraints, and demonstrates the feasibility of developing of multimedia monitoring tools. As future work, will be implemented a functionality for environmental monitoring using cameras and will also be studied the cost-benefit ratio of energy consumption, resource availability, quality of service and quality of information.

Acknowledgements

The authors would like to thank the support of CNPq and INCT NAMITEC by enabling the development of this research.

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