Geolocation and monitoring platform for extensive farming in mountain pastures

Alvaro Llaria[1], Guillaume Terrasson[1], Harbil Arregui[2], Amélie Hacala[1]

[1]ESTIA, Technopole Izarbel, 64210 Bidart, France
{a.llaria, g.terrasson, a.hacala}@estia.fr

[2]Vicomtech, Mikeletegi Pasealekua, 57, 20009 Donostia, Spain
harregui@vicomtech.org

***Abstract*—Nowadays, interconnected ubiquitous objects are more and more present in different applications as a technical solution to collect, every time and everywhere, great amounts of data which are accessible through the Internet. One interesting area of application is the monitoring of cattle, in order not only to improve the farming working conditions but also to better know the behavior of the animals. In this work, a geolocation and monitoring platform oriented to extensive farming in mountain environments is presented. The proposed solution is composed of low power long range communication geolocation devices and a dedicated interface, accessible by means of different portable devices, which allows users to access and study the collected data.**

Keywords—ubiquitous computing; geolocation; wireless communication; low energy consumption; extensive farming

I. INTRODUCTION

The Internet of Things (IoT) has experimented an important expansion during the last years mainly due to the evolution and miniaturization of electronic devices and to the improvement of wireless communication networks. The interest of IoT is its capacity to collect, using interconnected ubiquitous objects, environmental data which could be processed and analyzed by final users through different platforms such as computers, smart phones, etc. Then, nowadays, IoT applications cover a wide range of areas such as medical, manufacturing, home automation, scientific studies or sport activities.

In this context, Global Navigation Satellite System (GNSS) combined with radio transceivers embedded into collars have been employed since a number of years by ecologists and scientists. These technologies are used in order to track animals in the field and to monitor their behavior from the analysis of data issued from their movements [1, 2]. Furthermore, in the frame of extensive farming, the capability of these technologies in order to propose and implement virtual fencing solutions has also been studied [3, 4].

Nowadays, several solutions are already in the market mainly to track savage animals in open spaces like birds [5] or roe deer [6]. Nevertheless, the application of these technologies to monitor and eventually control the cattle seems to be in a research stage, because of a number of constraints [7], mainly in terms of energetic autonomy of embedded systems, wireless network coverage and communication network architecture. The work presented in this paper proposes a geolocation platform for extensive farming which offers long autonomy and wide coverage by means of a specific wireless communication network. The information issued from the exploitation of the data collected using the proposed system confirms the utility of new technologies to offer novel services that improve the farming working conditions. In this frame, this article shows that this type of platform is able to answer different societal and technical challenges concerning the extensive farming in mountain environment.

The paper is structured as follows. Section II shows the main challenges to face up in the frame of farming and technologies applied to extensive breeding. The technical aspects of the proposed solution are described in depth in Section III. In Section IV, the main results obtained during the tests in open air are analyzed and discussed. Finally, Section V concludes this paper, including a description of the future work for the improvement of the developed platform.

II. STATE OF THE ART AND CHALLENGES

A. Farming challenges

From several years, different approaches have been proposed in order to enhance the livestock production [8], either from the bioengineering area ("in vitro meat" or genetic modifications in example) or based on Information and Communications Technologies (ICTs). The wide penetration of new ICTs in many societal areas is an interesting opportunity to improve the farming conditions in rural areas, proposing solutions relatively non-intrusive for the animal and less controversial than those issued from the biological engineering. This is the aim of the Precision Livestock Farming [9], based on the application of the electronics and communication technologies as a solution to optimize the farming production. Then, the IoT must give the definitive impulsion to generalize the application of new technologies in the agriculture.

From the point of view of the final user, there are several aspects to be taken into account which can motivate a farmer to adopt those new technologies [10]: to have a positive vision of new technologies, the perception of the easiness to use those technologies, the perception of the real utility of the proposed innovation, and to have the impression that the proposed technology accomplish the objectives of the farmer. In this context, a technology will be adequate if it helps the farmer to accomplish his daily tasks, respecting at the same time his liberty to decide the way and the moment to carry out those tasks.

978-1-4799-7799-4/15/$31.00 ©2015 IEEE

As an example, the employ of GNSS collars by farmers in order to achieve the geolocation of animals constitutes an additional tool to survey not only the position of an animal but also its behavior, its health and, in addition, to obtain complementary information about its societal interactions with the cattle [11]. Moreover, the analysis of the collected position data must be also used by prairie users in order to ensure a better management of the pasture resources, guiding the cattle to the less exploited grazing areas and, consequently, favoring the renewal of the grass of the exhausted pastures [12, 13].

B. *Technical challenges*

The geolocation of animals in mountain pastures implies a number of technical challenges that must be overcame in order to propose an attractive solution for farmers.

One of the most important constraints is the energy consumption. GNSS solutions are relatively power-hungry, and this fact impacts dramatically on the autonomy of the embedded electronics. The simplest solution to override this problem is to embed more performing batteries, but this option is not suitable from the point of view of system size and weight that must be carried by the animals. Another strategy consists on modifying the duty-cycle or minimizing the on-time of the electronics [14, 15], which implies the loss of data that could be interesting for the animal monitoring. Compression of geolocation transmitted data is a possibility [16], but this solution requires an algorithm that increases the complexity and the computational charge of the system. The recent research concerning energy harvesting techniques [17, 18] could be another interesting solution, which must be still improved to reach a correct efficiency.

Another technical challenge concerns the wireless communication solution to be adopted. Nowadays, WSNs [19, 20] or mobile applications [21] employ classical communication protocols such as ZigBee, Bluetooth, WiFi or GSM. Moreover, the scientific literature [22, 23] has demonstrated that Wireless Sensor Networks (WSNs) can be a solution to enhance the tracking systems. In fact, the activities carried out in this area are focused on specific network protocols that could be used to improve the QoS of the whole system. Nevertheless, for animal geolocation purposes in wide open environments, these types of solutions are not really adapted in terms of range coverage, data rate, energy consumption and costs.

The presentation of animal tracking data by means of Human-Machine Interaction (HMI) platforms also constitutes a major defy from the point of view of the difficulty to visualize and represent movement data [24]. From recent years, visualization platforms are mainly based on web solutions, such as Google Maps [25], in order to show the geolocation positions. Other solutions propose a dedicated interface to improve the data delivered by satellites [26] or telemetry geolocation solutions [27]. Finally, several visualization platforms are devoted to specific satellite-based wildlife animal tracking commercial systems to pet tracking solutions for the general public. Monitoring cattle in mountain pastures in the present project needs a medium-range complexity platform for stockbreeding professionals with ease of use and geo-fencing capabilities that could be run in a wide variety of desktop or mobile devices.

III. PROPOSED SOLUTION

The main goal of the work presented in this article is to implement a system capable of determine the location of animals in mountain pastures during the summer period, taking into account the challenges analyzed in Section II.

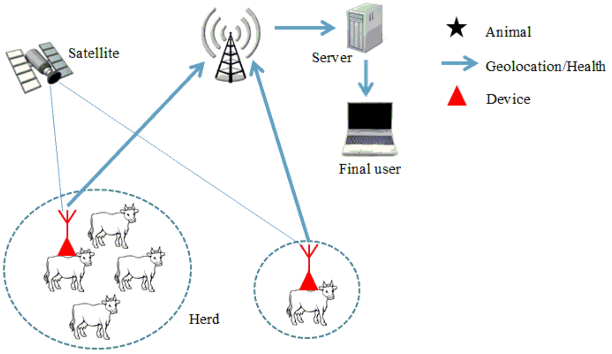


Fig. 1. Global architecture of the platform.

The developed platform is globally composed of two main parts: the geolocation devices and the visualization user interface. Figure 1 shows the architecture of the whole system. The ideal solution is to know the position of each animal from each herd. But, in order to limit the cost of our proposal, we have chosen another strategy which is to determine the location of the animal that leads the herd, because the rest of congeners usually follows it or keeps near from it [28].

The final user will be able to know where their animals are by means of a dedicated interface, accessible from different platforms (PC, lap table, smartphone or tablet). From the positions collected along the time, other information about the animal could be deducted, mainly its health or behavior.

A. *Geolocation devices*

First of all, it is important to point up that animals rest in the summer pastures at least 7 months, within a surface up to 2000 hectares.

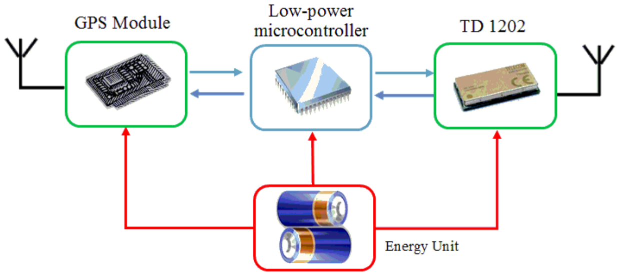


Fig. 2. Block diagram of the geolocation devices.

Therefore, the challenge in terms of geolocation devices was to develop a solution capable of operate during 7 months without any replacement of batteries by the user, assuring at the same time a good coverage and a size and weight which does not disturb the animals. As it can be seen in Figure 2, four main parts constitute the electronics of the developed geolocation devices:

- The GNSS module. The chosen technology has been the Global Positioning System (GPS). In order to face up the problem concerning the energy autonomy of the devices, the positions are acquired once an hour.
- The wireless communication module [29]. This module allows transmitting the geolocation collected data to a dedicated server by means of the wireless communication technology developed by SIGFOX [30]. This kind of technology is oriented to long-range transmission with low-rate and low-power consumption. By choosing this wireless communication solution, two major problematic have been resolved: the large surface to be covered and the minimal energetic consumption of the geolocation devices. As it has been said before, the geolocation positions obtained by the GPS are transmitted once an hour, which is an adequate data rate for the SIGFOX network.
- An extreme low-power consumption microcontroller that manages the whole electronic devices.
- The energy unit, which consists of two lithium batteries capable to offer the desired energetic autonomy.

TABLE I. CHARACTERISTICS OF THE GEOLOCATION DEVICES

Electrical specifications	***GPS positions capture rate***	1 per hour
	Messages transmission rate	1 per hour
	Autonomy	7 months
Mechanical specifications	***Volume***	114 x 70 x 30 mm
	Weight	150 grams

Fig. 3. Developed geolocation devices: general aspect and positionning on the animal's collar.

Taking into account that devices must be operational without any user intervention during the grazing period, and considering the severe weather conditions in mountain pastures even in summer, the waterproofness of the circuit packaging has been also assured to avoid the humidity presence into the device.

The complete geolocation device is shown in Figure 3, whereas its main characteristics are summarized in Table I.

B. *Visualization user interface*

In order to assist owners monitoring animals during summer grazing in mountain pastures, a visualization web platform has been provided.

This platform consists of:

- MySQL database and Tomcat server.
- Data retrieval module to periodically extract positions from the SIGFOX backend via its REST API.
- A set of Java web services for users, animals, positions, virtual fence and statistics management.
- HTML5 web interface with maps.

The platform offers the following functionalities for the authorized users that log in.

As we can see in Figure 4, the main page displays a map where the last position received from each device is shown with a clickable marker containing the animal info sheet. The second menu option helps filtering the positions for a given animal according to a time interval.

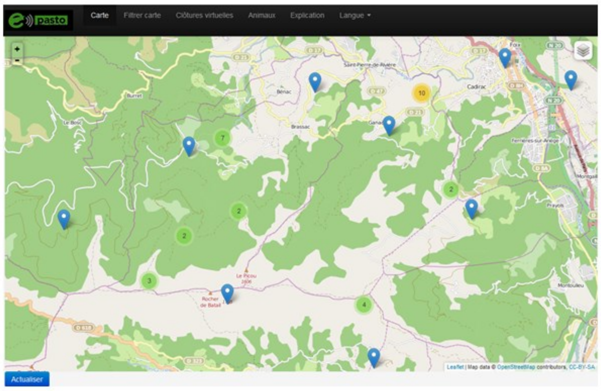
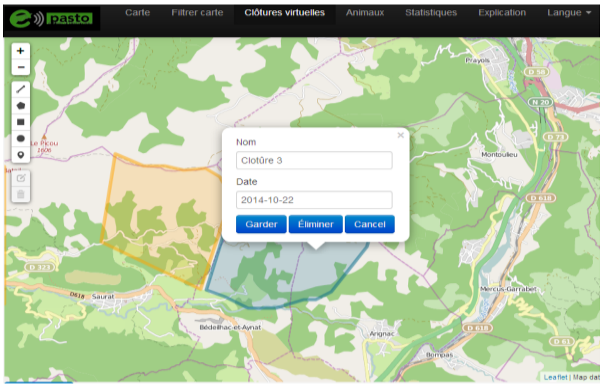


Fig. 4. Visualization user interface, showing several animals' positions.

The third menu option provides the functionalities for creating, editing and deleting virtual fences over a map (Figure 5), so that each user can easily manage the zones.

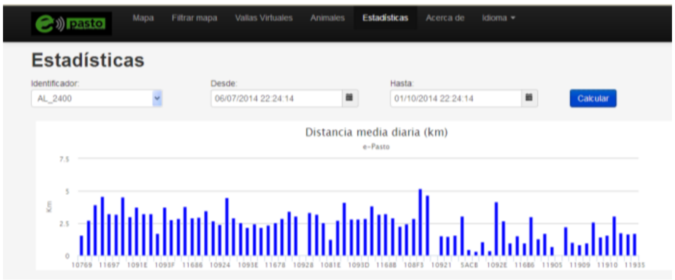

Nom: Clotûre 3

Date: 2014-10-22

Fig. 5. Visualization user interface: creation of virtual fences over a map.

Then, contrary to other virtual fencing solutions [31] which propose the transmission of remote stimulation to the animal in order to induce a movement which changes their location, point-in-polygon geometric computations [32] are used to decide whether an animal position is found to be inside an area (fence) or not, thus generating an alarm on the user interface.

The fourth functionality is for editing the animal information regarding the age, sex, species or the owner among others. The last option summarizes and exploits the collected data to show some statistics and results (Figure 6).



Estadísticas

Identificador: AL_2400

Desde: 06/07/2014 22:24:14

Hasta: 01/10/2014 22:24:14

Fig. 6. Visualization user interface, showing daily average distance statistics.

The statistics include total and average daily distances for each animal, as well as the rate of positions inside/outside each virtual fence. Moreover, in addition to the standard web application, a simpler geolocation-only version has been developed to allow offline maps. Since data access is very limited in mountain areas via mobile networks, in this version map tiles are downloaded once (when good internet connection is available), and cached for a later use.

IV. EXPERIMENTAL RESULTS

This Section presents the experimental results obtained during the field tests, along with a discussion about the contributions and the potentials of the proposed solution.

A. *Experimental area and environment*

Two experimental zones have been chosen in order to realize the geolocation tests:

- Prat d'Albis in Ariège, France.
- The Urola-Erdia region in Gipuzkoa, Spain.

The main characteristics of these two zones are shown in Tables II and III, respectively.

TABLE II. CHARACTERISTICS OF THE PRAT D'ALBIS IN ARIÈGE

Surface	2000 ha
Orography	Mountain with flat surfaces
Altitude	From 900 m to 1600 m
Number and kind of equipped animals	34 bovines 19 sheep 2 horses
Time duration of the tests	6 months (from May to October 2014)
Number of SIGFOX antennas	3

TABLE III. CHARACTERISTICS OF THE EXPERIMENTAL ZONE IN UROLA-ERDIA

Surface	100 ha
Orography	Scarped mid mountain
Altitude	From 400 m to 600 m
Number and kind of equipped animals	27 bovines
Time duration of the tests	5 months (from July to November 2014)
Number of SIGFOX antennas	1

As it has been shown, these two areas are quite different in terms of surface, orography, environmental conditions and number of animals. The animals equipped by the geolocation devices during the experimental tests were real animals chosen by the farmers. Then, the tests were realized in real conditions, not in an ideally experimental scenario, during the period of summer pastures.

B. *Results and analysis*

Figure 7 shows the performance of the devices in terms of successful transmission of messages over the SIGFOX network.

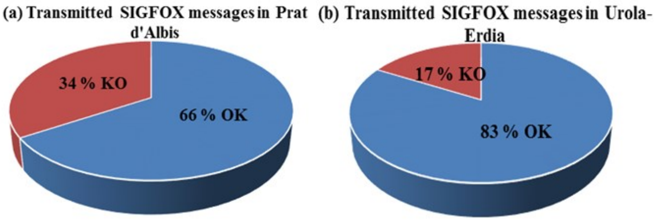


Fig. 7. (a) % of message received by our platform using the SIGFOX network in Ariège and (b) % of message received by our platform using the SIGFOX network in Gipuzkoa.

The results issued from the experimental phase concerning the performance of the wireless communication network shows that it could be improved for wide areas. In fact, in the first experimental zone in Ariège (Prat d'Albis), it exists a lack of coverage in some zones, mainly due to the mountain orography. This situation could be enhanced by optimizing the antenna positioning in the tests areas.

Nevertheless, some results for this experimental zone show that more than 3 antennas have received the SIGFOX messages, confirming the potential of long range (>10 km) communication of this technology. On the other hand, the experimental zone in Gipuzkoa, Urola-Erdia, has a smaller surface, which can be more easily covered by only one SIGFOX antenna, as it can be confirmed regarding the high tax of correct messages transmitted through the network.

The performance of the obtained GPS geolocation measures is presented in Figure 8.

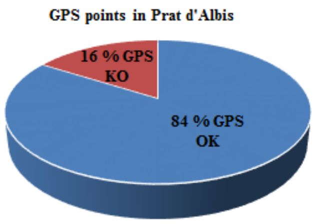


Fig. 8. % GPS positions obtained by the geolocation devices in Prat d'Albis.

These results takes only into account the data of the GPS received messages, that is, a GPS KO means that the obtained position is corrupted or it shows a position out of the experimental zones. The analysis of the first results shows that only few messages received by our platform in Ariège have not contained a correct GPS position, as shown by Figure 8, which is very promising. In Prat d'Albis, the flat surfaces of the mountains assure a good reception of the signal from the satellites, allowing to obtain correct GPS positions. It is also important to point up that a tradeoff have must been made between the time employed by the GPS module to fix the position and the optimization of the geolocation device autonomy, that has also been an impact in the obtained results.

Moreover, several precision tests were carried out with the geolocation devices before they were installed over the animals. In order to obtain the static precision error, some devices were placed outdoor of the ESTIA building. Figure 9 shows the geolocation points obtained by one of the devices that was always placed at the same position. The precision presents a classical value for the GPS. In fact, the measured dispersion is about 20 meters around the real position of the device.

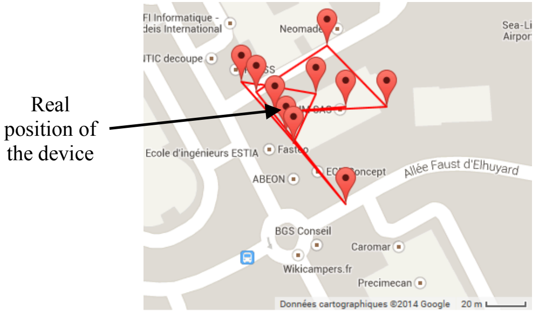


Fig. 9. Geolocation points obtained by one device placed at the same position.

Finally, we notice that the autonomy in energy of the embedded device is quite similar to the defined needs, allowing the acquisition of more geolocation data per day. The statistical analysis of battery duration of the geolocation devices is shown in Figure 10.

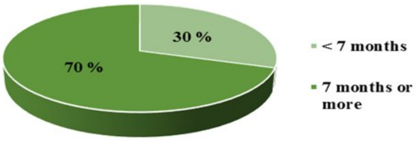


Fig. 10. Battery duration of geolocation devices.

C. *Limitations and discussion*

Regarding the obtained experimental results, it can be noticed that the main limitation of this solution is the low rate of geolocation positions measurement, which assures at least 7 months of battery autonomy. It will be necessary to find out new solutions that increase the number of measured positions keeping the same battery lifetime. Concerning the geolocation collars limitations, it has been mandatory to avoid any turn of the collar around the neck of the animal in order to ensure the correct reception of the GPS signal by the devices. For this purpose, cowbells have been employed to ballast the collars. Another solution more integrated into the collar should be adopted for the future. Finally, the HMI interface has been developed taking into account the farmers' advice, resulting in a simplified user-friendly navigation environment. From this point of view, the interface can be considered as the less limiting element of the whole geolocation platform.

In spite of these main limitations, the first experimental results prove that the developed platform is a promising solution which offers different benefits for the breeding in mountain pastures. Taking into account the different extensive farming challenges, this type of platform can be a good option to help farmers in their daily work, offering the capability of a remote surveillance of their animals without the necessity of unnecessary displacements. The result is a better organization of the farmer's daily tasks. In addition, as it has been shown during the description of the proposed visualization interface, the collected data could be exploited not only in order to obtain the geolocation position but also, after an additional analysis of the data, to deduce other supplementary information to survey the animal's health or activity (in example, detection of an animal that is being attacked by a predator or of a mare that is foaling). In the future, other kind of sensors could be added to the developed geolocation devices to collect more accurate information about the health and the herd behavior.

The proposed solution is also an essential part of a complete system of virtual fencing. Once the position of an animal has been obtained, our HMI interface allows to the user to determine if the animal is into a forbidden zone or near to a dangerous site. In both cases, the platform generates automatically in the interface an alarm which can be transmitted by means of a SMS message to the farmer. Instead of employing remote interactions to induce movements to the animals, because of this kind of solutions are in an experimental stage due to the complexity to understand the animal behavior [33], the proposed platform constitutes a virtual fencing application which brings an alternative solution to the final user. In this context, our platform could also be used to optimize the management of grazing resources without negative remote interaction with animals. Through the HMI interface, the farmer is able to easily modify the defined virtual fences to establish new allowed pasturing zones.

V. CONCLUSION AND PERSPECTIVES

This paper has presented a platform composed of geolocation electronic devices which employ a long range wireless communication network and a HMI interface to survey animals in mountain grazing areas. The promising results issued from the experimental tests demonstrate that this type of technology can be used to help farmers, improving their work conditions. Even more, scientists can employ the platform as a basic tool to study the animal social interactions, (leader identification, cohesion of the group) and in general, the animal behavior. For future work, the developed system should be optimized in terms of the overall performance of the geolocation devices and the functionalities offered by the HMI interface. Moreover, new solutions concerning the data collection must be applied to improve the current methods employed for detecting diseases or an abnormal behavior of animals. The proposed platform has contributed to validate the potential of ubiquitous technologies applied to activity sectors which have been traditionally distant from new technologies such as the extensive mountain farming.

ACKNOWLEDGMENT

The work presented in this paper has been developed in the frame of the project e-Pasto (pilot project of AGRIPIR), which has been financially supported by the European Commission in the frame of the Spain-France-Andorra Territorial Cooperation Operational Program (POCTEFA 2007-2013) and the FEDER funds.

REFERENCES

[1] N. Tomkins, P. O'Reagain, "Global positioning systems indicate landscape preferences of cattle in the subtropical savannas," The Rangeland Journal, vol. 29, pp. 217-222, 2007.

[2] E.D. Ungar, Z. Henkin, M. Gutman et al., "Interference of animal activity from GPS collar data on free-ranging cattle," Rangeland Ecology Management, vol. 58, pp. 256-266, 2005.

[3] Z. Butler, P. Corke, R. Peterson, D. Rus, "From robots to animals: virtual fences for controlling cattle," The International Journal for Robotics Research, vol. 25, pp. 485–508, 2006.

[4] C. Umstatter, "The evolution of virtual fences: a review," Computers and Electronics in Agriculture, vol. 75, pp. 10-22, 2011.

[5] W. Wiltschko and R. Wiltschko, "Global navigation in migratory birds: tracks, strategies, and interactions between mechanisms," Current Opinion in Neurobiology, vol. 22, pp. 328-335, 2012.

[6] A. Coulon, N. Morellet, M. Goulard et al., "Inferring the effects of landscape structure on roe deer (Capreolus capreolus) movements using a step selection function," Landscape Ecology, vol. 23, pp. 603-614, 2008.

[7] K.H. Kwong, T.T. Wu, H.G. Goh et al. "Implementation of herd management systems with wireless sensor networks," IET Wireless Sensor Systems, vol. 1, pp. 55-65, 2011.

[8] P.K. Thornton, "Livestock production: recent trends, future prospects," Philosophical Transactions of the Royal Society Biological Sciences, vol. 365, pp. 2853-2867, 2010.

[9] C. Wathes, "Precision livestock farming for animal health, welfare and production," 13th International Congress in Animal Hygiene (ISAH), pp. 397-404, 2007.

[10] D.J. Panell, "Social and economic challenges in the development of complex farming systems," Agroforestry Systems, vol. 45, pp. 393-409, 1999.

[11] E.L.C. Shepard, R.P. Wilson, F. Quintana et al., "Identification of animal movement patterns using tri-axial accelerometry," Endangered species research, vol. 10, pp. 47-60, 2008.

[12] D. J. Augustine, J. D. Derner, "Assessing herbivore foraging behavior with GPS collars in a semiarid grassland," Sensors, vol. 13, pp. 3711-3723, 2013.

[13] D. L. Gobbett, R. N. Handcock, A. Zerger et al. "Prototyping an operational system with multiple sensors for pasture monitoring," Journal of Sensor and Actuator Networks, vol 2, pp. 388-408, 2013.

[14] J. Ruiz-Mirazo, G.J. Bishop-Hurley, D.L. Swain, "Automated animal control: Can discontinuous monitoring and aversive stimulation modify cattle grazing behavior?" Rangeland Ecology Management, vol. 64, pp. 240-248, 2011.

[15] E.S. Nadimi, R.N. Jørgensen, V. Blanes-Vidal, S. Christensen, "Monitoring and classifying animal behavior using ZigBee-based mobile ad hoc wireless sensor networks and artificial neural networks," Computers and Electronics in Agriculture, vol. 82, pp. 44-54, 2012.

[16] R.N. Handcock, D.L. Swain, G.J. Bishop-Hurley et al., "Monitoring animal behaviour and environmental interactions using Wireless Sensor Networks, GPS collars and satellite remote sensing," Sensors, vol. 9, pp. 3586-3603, 2009.

[17] J. Colomer-Farrarons, P. Miribel-Catala, A. Saiz-Vela, J. Samitier, "A multiharvested self-powered system in a low-voltage low-power technology," IEEE Trans. on Industrial Electronics, vol. 58, pp. 4250-4263, 2011.

[18] A. Gutierrez, N. I. Dopico, C. Gonzalez et al. "Cattle-powered node experience in a heterogeneous network for localization of herds," IEEE Trans. on Industrial Electronics, vol. 60, pp. 3176-3184, 2013.

[19] V.C. Gungor, G.P. Hancke, "Industrial Wireless Sensor Networks: challenges, design principles, and technical approaches," IEEE Trans. on Industrial Electronics, vol. 56, pp. 4258-4265, 2009.

[20] L. Mainetti, L. Patrono, A. Vilei, "Evolution of wireless sensor networks towards the Internet of Things: A survey," 19th International Conference on Software, Telecommunications and Computer Networks (SoftCOM), pp. 1-6, 2011.

[21] D. Raychaudhuri, N. B. Mandayam, "Frontiers of wireless and mobile communications," Proceedings of the IEEE, vol. 100, pp. 824-840, 2012.

[22] T. Wark, P. Corke, P. Sikka et al., "Transforming agriculture through pervasive wireless sensor networks," IEEE Trans. on Pervasive Computing, vol. 6, pp. 50-57, 2007.

[23] D.L. Swain, G.J. Bishop-Hurley, "Using contact logging devices to explore animal affiliations: quantifying cow-calf interactions," Applied Animal Behaviour Science, vol. 102, pp. 1-11, 2007.

[24] N. Andrienko, G. Andrienko, "Spatial generalization and aggregation of massive movement data," IEEE Trans. on Visualization And Computer Graphics, vol. 17, pp. 205-219, 2011.

[25] V. Raj Jain, R. Bagree, A. Kumar, P. Ranjan, "wildCENSE: GPS based animal tracking system," International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), pp. 617-622, 2008.

[26] J. Choi, S. Lee, S. Gigitashvilli, J. Wilson, "Situation awareness tool for Global Argus," IEEE Symposium on Visual Analytics Science and Technology (VAST), pp. 213-214, 2007.

[27] J. Hunter, C. Brooking, W. Brimblecombe, "OzTrack-e-Infrastructure to support the management, analysis and sharing of animal tracking data," IEEE 9th Int. Conf. on eScience, pp. 140-147, 2013.

[28] N. Correll, M. Schwager, D. Rus, "Social control of herd animals by integration of artificially controlled congeners," 10th International Conference on Simulation of Adaptive Behavior (SAB), pp. 437-446, 2008.

[29] "TD1202. High-performance, low-current SIGFOX gateway. Rev 1.0," Telecom Design, 2012.

[30] "M2M and IoT redefined through cost effective and energy optimized connectivity," SIGFOX Whitepaper, 2014.

[31] D. M. Anderson, "Virtual fencing-past, present and future," The Rangeland Journal, vol. 26, pp.65-78, 2007.

[32] S. Schirra, "How reliable are practical point-in-polygon strategies?" 16th European Symposium on Algorithms (ESA), pp. 744-755, 2008.

[33] M. Jouven, H. Leroy, A. Ickowicz, P. Lapeyronie, "Can virtual fences be used to control grazing sheep?" The Rangeland Journal, vol. 34, pp. 111-123, 2012.