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Research on the Architecture of Wildlife Observation and Communication System

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***Abstract*—With the development of Internet of Things (IOT) industry, research on wildlife monitoring meets with innovative progress. In this manuscript, we analyze the development of communication technologies, and discuss the architecture of wildlife observation and communication system from three aspects: component, communication platform, and research application. We introduce our preliminary research on a real-world bird tracking system, and discuss the system's working process and mechanisms such as power saving, data storage, and communication area indication. We introduce initial system applications on tracking and behavior recognition, and give some considerations on the architecture implementation.**

Keywords—Wildlife observation and communicaiton system architecture; wildlife tracking; power saving; behavior recognition

I. INTRODUCTION

With the development of Internet of Things (IOT) industry, research on scientific observation meets with innovative progress. In the past 15 years, there are many research projects on environment and wildlife observation, such as GreenOrbs [1], Live E [2], ZebraNet [3], etc.

The observation and communication infrastructure includes components such as data acquisition, data transmission, and data management. Open Geospatial Consortium (OGC) Sensor Web Enablement (SWE) [4] defines web service interfaces and communication protocols for the heterogeneity of sensor communications.

In this paper, we introduce our research on the architecture of wildlife observation and communication system.

This paper is organized as follows: Section II introduces the wildlife observation and communication technologies; Section III introduces the architecture of wildlife observation and communication system; Section IV introduces our preliminary research on a bird tracking system; in Section V, we focus on the positive outcomes and give some considerations on on-going research.

II. WILDLIFE OBSERVATION AND COMMUNICATION TECHNOLOGY

Location tracking is representative application for wildlife observation. The wildlife's movement sometimes covers wide area, so researchers used to apply satellite for tracking. Representative satellite positioning systems include GPS, Glonass, Galileo, and Beidou. There are kinds of communication technologies:

(1) Satellite Communication.

Satellite communication systems such as Argos, Global Star, Iridium, etc, are used for wildlife tracking in the past 30 years [5]. Satellite communication could cover world-wide area. However, it is always used for rare wildlife because of the high communication cost.

(2) Radio communication.

Radio is used for wildlife tracking in the past 60 years. The location of a radio-marked wildlife can be estimated using triangulation [6]. Researchers also use antenna directionality and signal strength information to find the transmitter. However, the localization accuracy is low, and sometimes it is difficult for the user to follow the wildlife in wild area.

(3) Recent communication trends.

With the development of mobile communication and wearable computing, GPS data can be transferred via GSM, 3G, and LTE. However, vast areas lack mobile communication services, so data storage mechanism is an important issue.

Short distance communications, such as Wireless Sensor Network (WSN), IEEE 802.15.4, WiFi, Radio Frequency Identification (RFID), etc, have been widely used for data transmission in wildlife observation and communication systems in the past 10 years [7]-[13]. For different wildlife species, it is recommended to apply different communication technology according to the living habits.

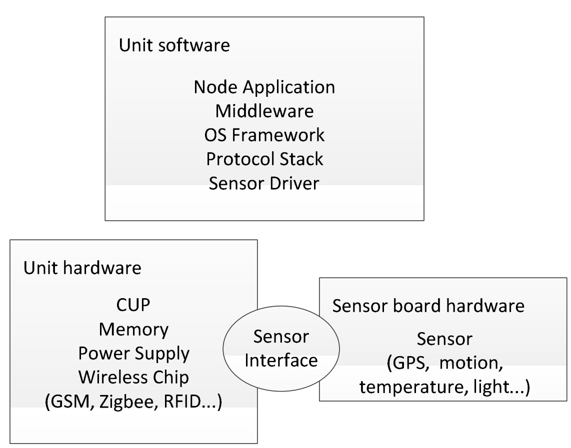

Fig.1. Components of wildlife observation and communication unit

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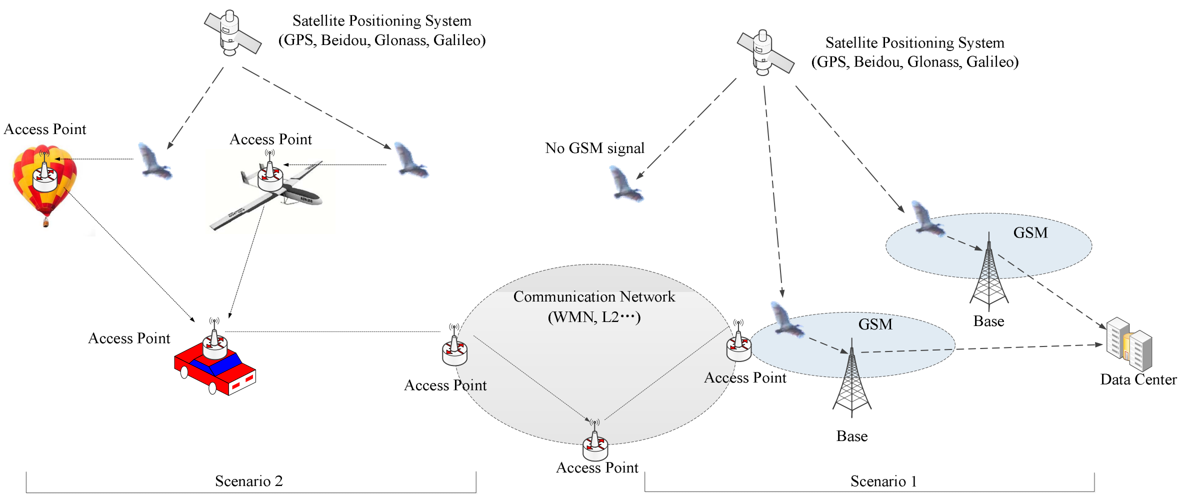


Fig.2. Scenarios of bird tracking

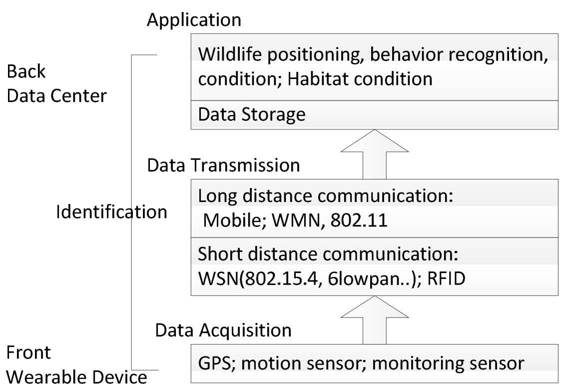


Fig.3. Architecture of wildlife observation and communication platform

III. ARCHITECTURE OF WILDLIFE OBSERVATION AND COMUNICATION SYSTEM

Figure 1 shows the components of a wildlife observation and communication unit. The unit includes software, hardware, sensor interface, and sensors.

Figure 2 shows the scenarios of wildlife (bird) tracking:

Scenario 1: when the bird tracker is in the effective GSM communication area, the tracker sends the location data to the base station, then to data center through network. While the tracker is out of the effective range, it stores the data in the memory and waits for the communication beacon from the base station.

Scenario 2: when the bird tracker is in the effective wireless communication area, the tracker sends the location data to the base station through an Access Point (AP). An AP could be set up on drone, balloon, or vehicles, and it communicates with base station through Wireless Mesh Network (WMN) or Layer 2 communication. An AP performs as a Mesh Router (MR) in WMN.

Many IOT architectures have been proposed in the past 10 years [14]. For Networked Auto-ID and uID IOT, each device (or tag) has an global unique ID for identification in the communication platform, and main data processing is in the back information server; while for Ubiquitous Sensor Network (USN), Machine-to-Machine (M2M), SENSEI, IOT-A, the platforms could integrate different identification or sensing network.

We propose the architecture of a wildlife observation and communication system, as is shown in Figure 3. A global unique ID for wildlife identification is required, since some wildlife moves in wide area, or even different countries. The front wearable device and gateway deal with data acquisition and transmission task, while the data center deals with data processing and application task. The representative scientific research applications include wildlife tracking, migration route, behavior recognition, habitat environment observation, etc.

IV. PRELIMINARY RESEARCH ON WILDLIFE OBSERVATION AND COMMUNICATION SYSTEM

We would like to set up a practical wildlife observation and communication platform for scientific research in ecology and zoology field, on the base of the proposed architecture. Here we introduce preliminary research.

A. Tracking Device

According to the scenarios we discussed in Section III, two kinds of tracking devices are required: mobile communication (GSM) based tracker (G-tracker), and wireless communication based tracker (W-tracker).

For G-tracker, we apply a GPS module for positioning and a GSM module for data transmission. There are several sensors on G-tracker to acquire data such as acceleration, height, illumination, temperature, etc.

Power consumption is important for wildlife tracking device. In hardware component, we use high energy lithium battery, and apply solar panel for power charging. In software component, the cooperation of data storage, power saving, and effective communication area indication mechanisms is required in the working process, for promoting the system's working efficiency.

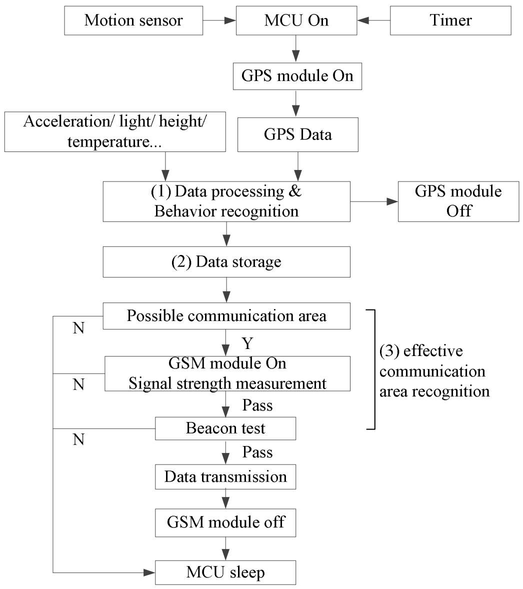


Fig.4. Architecture of wildlife observation and communication platform

TABLE I. DATA SET FORMAT

Item	Content
ID	A unique ID for wildlife indication
GPS	GPGGA data
Sensor data	Acceleration, height, light, temperature data…
Status	0: resting; 1: flying; 2: flying→resting; 3: resting→flying
Power	Power left in the battery
Signal Stenght	GSM signal strength

B. *Working Process*

Figure 4 shows an overview of G-tracker1's working process. In most occasions, the Microcontroller Unit (MCU) works in a certain circle, for example, 20 minutes, and a timer is used to wake up MCU. For some research applications, such as monitoring a bird's movement in short time period, the MCU is required to work in time according to the bird's behavior status. Here we introduce 3 steps in working process:

(1) The MCU acquires and combines the GPS and sensing data, and stores data into the memory. Basic behavior recognition, such as "resting" and "flying", is performed on the base of the sensing data, and the status is indicated in "Status" item. A representative data set is shown in Table I;

(2) A migration bird lives in wild environment, in most occasions there are not enough GSM stations. While a bird flies high in the sky, the GSM signal cannot reach the tracker. The memory may get full if the bird stays long time beyond the communication range. In storage mechanism, we indicate the status "2" and "3" data as important data, and the new data only overwrites the non-important data when the memory buffer is overflowed;

(3) The effective communication area recognition mechanism includes three steps: (a) the MCU checks whether the current location is in the possible communication area; then (b) enables the GSM module, and checks the GSM signal strength; (c) the MCU starts beacon test. In beacon test, the MCU sends query beacon to the base, if the base sends back a confirmation beacon within an interval, then the MCU starts the data transmission. The quality of service (QoS) of data transmission will be discussed in the near future.

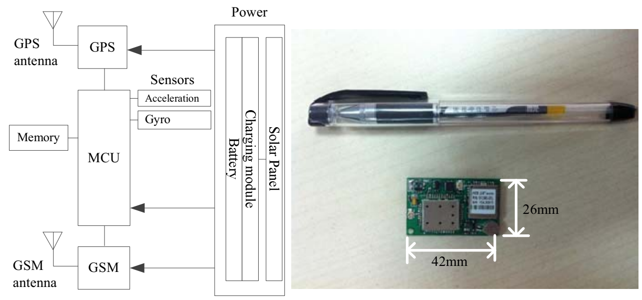


Fig.5. G-tracker1 and its structure

TABLE II. SPECIFICATIONS OF G-TRACKER1

Item	Specification
Size	42mm×26mm
Weight	6.0g (without battery)
Battery	300mAh; Current: Maximum 1A; Typical 0.5A
MCU	Power: 2.5-5.5v; Sram: 4kB, Flash: 32kB Current: Typical 4-6mA; Idle 1mA; Power off 1mA
GPS	Frequency: 1575.42Hz; C/A Code:1.023MHz; Sensitivity:-165dBm; Time to first Fix:hot start:<1s; cold start: <31s; Current: Typical 20mA
GSM	Power: 3.2-4.8v Quad-band: GSM850/EGSM900/DCS1800/PCS1900 MHz Current: Typical 20mA
Sensors	Gyro: full-scale: ±250,±5000,±1000,±2000dps Acceleration: full-scale: ±2g,±4g,±8g,±16g Total current: Typical 3mA
Antenna	GPS: Gain 3dB; GSM:Gain 3dB
Memory	4MB

C. *G-tracker1*

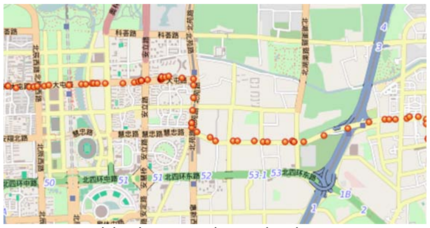
We have developed a practical G-tracker (G-tracker1), as is shown in Figure 5. Table II shows the specifications and the power consumption of each component. The total typical current is less than 50 mA, and the idle current is 0.8 mA, theoretically. We apply a solar panel for charging, and the maximum charging current is 30 mA. The GPS module works in a certain circle, and is enabled by MCU. Theoretically, when the circle is 1 hour, G-tracker1 could work for around 8 days without solar charging, and the memory could store at most 65536 logs before overflow.

D. *Initial Experiments*

We performed initial experiments using G-tracker1, including tracking and behavior recognition experiments.

Figure 6 (upper) shows a tracking experiment in city area, the positioning interval is 1 minute. More experiments in field areas will be performed in the near future.

Figure 6 (lower) shows an example of a goose's behavior recognition experiment using an acceleration sensor unit on its back. With the development of wearable technology, smart



Positioning experiment in city area

Behavior recognition experiment

Fig.6. Initial Experiment

band and smart watch apply gyro and acceleration sensors to recognize user's behavior, such as sleeping status, sports style, walking steps, etc. We are developing recognition algorithms for some wildlife.

V. CONSIDERATIONS ON THE ARCHITECTURE

Several issues are under discussion in our on-going research for wildlife observation and communication platform:

(1) Identification mechanism: we would like to apply an existing DNS (Domain Name System)-like identification platform in the architecture;

(2) W-tracker: fixed APs should be set up near habitat to receive data from the W-tracker. The effective communication range is not so far because of the limited power supply. Performance comparison between G-tracker and W-tracker will be performed in the near future. A mix function of "G" and "W" tracker could provide wildlife tracking and monitoring service in both city and field area.

(3) Mobile AP and WMN testbed: a WMN testbed near wildlife habitat is required for the real-world W-tracker experiment. Also we set up a MR on a drone or a vehicle working as a mobile AP.

Observation devices may have kinds of sensors and interfaces, so standardization in gateway, storage, and application is important for the integration of heterogeneous sensor networks. Also, with the popularization of next generation internet and 6lowpan standard, a more networked platform is required in the architecture.

VI. CONCLUSION

This paper discusses the architecture for wildlife observation and communication system, from the aspects of construction component, communication platform and research application.

In the preliminary research, we discuss the working process of the observation and communication unit, especially on the power saving, data storage, and effective communication area indication mechanisms. We develop a G-tracker and perform initial tracking and wildlife behavior recognition experiments. We also discuss our considerations on the architecture on on-going research.

The proposed architecture and practical system implementation provides examples and guidelines for the wildlife observation and communication research in ecology and zoology field.

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References

[1] Y. Liu, Y. He, M. Li, J. Wang, K. Liu, and X. Li, "Does wireless sensor network scale? A measurement study on GreenOrbs," IEEE Transactions on Parallel and Distributed Systems. Vol. 24, No. 10, PP. 1983-1993, October 2013.

[2] H. Esaki, H. Sunahara, "Live E! project: sensing the earth with internet weather stations," International symposium on applications and the internet. Vol. 10, PP. 18-25, 2006.

[3] P. Zhang, C. M. Sadler, S. A. Lyon, and M. Martonosi. Hardware Design Experiences in ZebraNet. ACM Confernce on Embedded Networked Sensor Systems (Sensys), Baltimore, USA, Nov. 2004

[4] M. Botts, G. Percivall, C. Reed, J. Davidson, "OGC sensor web enablement: overview and high level architecture," Lecture Notes in Computer Science. Vol. 4540, PP. 175-190, 2008.

[5] W. S. Seegar, P. N. Cutchis, M. R. Fuller, J. J. Suter, V. Bhatnagar, and J. G. Wall, "Fifteen Years of Satellite Tracking Development and Application to Wildlife Research and Conservation," John Hopkins APL Technical Digest, Vol 17, Issue 4, pp. 305-315, 1996.

[6] M. R. Fuller, and T. K. Fuller "Radio Telemetry equipment and application for carnivores," Carnivore ecology and conservation: a handbook of techniques. Oxford University Press, Oxford, UK, pp. 152-168, 2012.

[7] W. Bouten, E. W. Baaij, J. Shamoun-Baranes, K. C. J. Camphuysen, "A flexible GPS tracking system for studying bird behavior at multiple scales," Journal of Ornithology. Apr. 2004, Vol. 154, Issue. 2, pp. 571-580.

[8] MATAKI Project: www.mataki.org

[9] K. Mase, T. Kajita, and Y. Zhang. A wide-area bird monitoring system using geographically distributed base stations. IEEE Wireless Communications and Networking Conference (WCNC), Quintana-Roo, Mexico, Mar. 2011

[10] J. Polastre, R. Szewczyk, A. Mainwaring, D. E. Culler, and J. Anderson, "Analysis of Wireless Sensor Networks for Habitat Monitoring," Wireless Sensor Networks. 2004, pp. 399-423.

[11] H. Yamamoto, S. Minomi, K. Nakamura, and K. Yamazaki. Development of Arkas Sensor Platform and Application for Heavy Snowfall Observation. 2012 IEEE/IPSJ 12th International Symposium on Applications and the Internet (SAINT), Izmir, Turkey, Jul. 2012

[12] Z. Yang, and H. Wu. FINDERS: A Featherlight Information Network with Delay-Endurable RFID Support. IEEE/ACM Transactions on Networking, Vol. 19, No. 4, Aug. 2011, pp. 961-974.

[13] V. Dyo, S. A. Ellwood, D. W. Macdonald, A. Markham, C. Mascolo, B. Pasztor, S. Scellato, N. Trigoni, R. Wohlers, and K. Yousef. Evolution and Sustainability of a Wildlife Monitoring Sensor Network. 8th ACM Conference on Embedded Netowrked Sensor Systems (SenSys 2010), Zurich, Switzerland, Nov. 2010

[14] J. Gubbi, R. Buyya, S. Marusic, and M. Palaniswami. Internet of Things (IoT): A vision, architectural elements, and future directions. Future Generation Computer Systems, Vol. 29, Issue. 7, September. 2013, pp. 1645-1660.