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Internet of Things (IoT) to Study the Wild Life: A Review

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ABSTRACT: Internet of Things (IOT) has emerged as an efficient technical support for the biological researchers. Present study has been focused on four applications of IOT used for wildlife monitoring; location tracking, habitat, *in situ* observation, and behavioral studies. IOT based monitoring unit for wildlife studies mainly includes sensing, communication, software and relative hardware components.

Keywords: Internet of Things (IOT); wildlife monitoring; habitat; environment and observation.

INTRODUCTION: The vision of smart world has been proposed for many years, and the research on Internet of Things (IOT), pervasive and ubiquitous computing, Cyber-Physical Systems (CPS), Wireless Sensor Network (WSN), Machine-to-Machine (M2M) systems have been discussed extensively in both the academic and industrial fields.[1-3] There is an increasing overlap and merger of research topics, and these technologies have been applied in many areas such as agriculture, disaster, health, environment, industrial control, transportation, etc.[4]

Similarly there has been a simultaneous modification in the components of IOT. These days, a typical IOT platform consists of three components: wireless communication, sensing and cloud service.[2, 5-7] As per the requirements of industrial field or research problem undertaken, the IOT architecture can be designed and made to perform accordingly.[1, 8-9]

In the past years, the natural environment is increasingly destroyed, and the monitoring and protection of wildlife is becoming more and more important. Development and survival of animals and plants is possible under appropriate environmental conditions. Here the environment conditions include both the biotic and abiotic factors related. The interaction of wild organisms with various factors of surrounding environment is very hard to ascertain as of limited direct social communication between wild organisms and human. This communication is far more apart in case of wild animals, which reside in their normal habitats. In order to understand the behavior of these organisms and make them survive on this planet for longer durations, we need to study the various aspects related to their normal life under natural environmental conditions. Presently there are many protocols are still more added in routine basis to ascertain such aspects. "Internet of Things (IoT)" is a promising software-hardware network including the same aspect related to study of animal life for their well-being.[1-4]

In this paper, we introduce the research on IOT for wildlife monitoring, and we mainly focus on four important and fundamental application topics: location tracking, habitat, natural environment(*in situ*) observation and behavior recognition. Data collected with this software may help the biologists working in the same field to understand the hazards faced by natural threatened species and ecosystems. This understanding will definitely be helpful in framing comparatively more effective conservation strategies. Here we have observed some frequently used research methods for animal and plant population ecology, and tried to investigate the current and futuristic applications of the "Internet of Things" technology.[1-2, 5-11]

Components of a typical wildlife monitoring unit: A typical wildlife monitoring unit consists of sensing, hardware, software, and communication components, as is shown in Figure 1. The hardware component includes Micro-Controller Unit (MCU), memory, and power supply (solar panel and/or battery). The software component includes lightweight operating systems (uCOS, TinyOS etc), drivers (memory driver, sensor driver etc.), identification mechanisms and middleware. The middleware deals with the issues on standardization of heterogeneous hardware and software interface, data stream processing, location and context analysis, etc.[8] In sensing component, we apply different sensors for different observing applications. For tracking, various localization methods are used such as, satellite positioning receivers namely GPS, Galileo, Glonass, Beidou etc. This variation in location techniques is preferred since wild animals have a broad roaming range. For behavioral studies, we apply acceleration, gyro sensors.[9-10] For the habitat environment observation; we apply monitoring sensors for parameters such as humidity, temperature, height, light, wind, camera, etc.

Table 1: Power consumption of G-tracker.

Item	Power consumption
MCU	Power: 2.5-5.5v; Current: Typical 4-6mA; Idle 1mA; Power off 1mA
Satellite	Current: Typical 20mA
GSM	Power: 3.2-4.8v; Current: Typical 20mA
Sensors	Total current: Typical 3mA

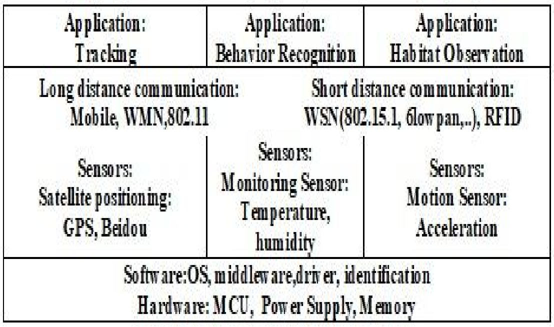

Figure 1: Construction of wild life monitoring unit.

There are two types of communication components: cellular and capillary. For cellular type, we apply Global Systems for Mobile Communication (GSM), Third and fourth Generation (3G/4G), Long Term Evolution (LTE) for long distance communication. In case of capillary type, IEEE 802.11 protocol can be applied for long distance communication, while IEEE 802.15.4, IETF, 6LoWPAN, Radio Frequency Identification (RFID) etc., can be applied for short distance communication.[11-12] Although both cellular and capillary communication components can be applied for long distance data transmission, the cellular component may cover nation-wide communication range and require big size base station; while the capillary component can provide better mobility and have self-organizing characteristic, the size of the base station could be small according to the application requirement.

Figure 2 shows typical scenario of wildlife monitoring. Habitat environment observation, sensor nodes are set up in the observation area, and are connected through sensor networks, such as IEEE 802.15.4. A sink node collects the observation data and connects with a backbone Wireless Mesh Network (WMN), such as IEEE 802.11s. The sink node performs as a mesh Access Point (AP) in WMN. Capillary communication is required in this work.[13-16]

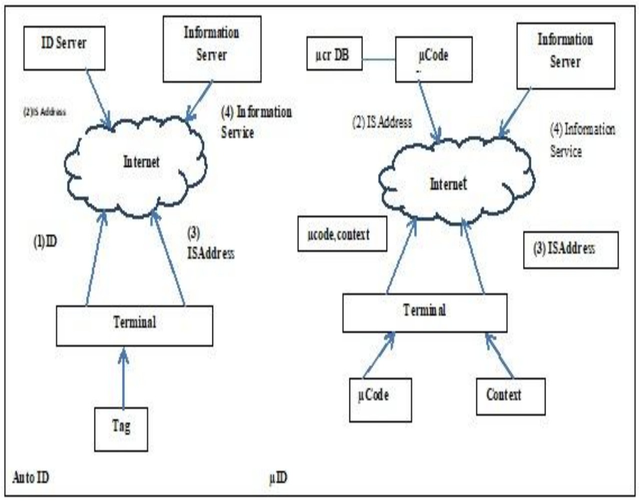

Figure 2: Auto-ID (left) and uID (right) architectures.

Functioning of IOT for wildlife monitoring:

a. Identification: Some wildlife organisms such as migratory birds travel in very wide area, so an ID is required for identification. The architectures of Networked Auto-ID and uID IOT are shown in Figure 3. Each device (or tag) has a global unique ID in the communication platform, and main data processing is in the back information server (IS). For wildlife tracking, the Networked Auto-ID and uID IOT could work similarly; while for habitat monitoring, the uID IOT may have better performance since the terminal in the architecture could acquire both identification (uCode) and context information. In practical implementation, we could record identification information in the analysis server and information server, and install a Near Field Communication (NFC) module in the hardware, and add unique identification code in the transmission data.[17-21]

b. Mobile Access Point(MAP): The mobile access point (MAP) should have two functions:

(1) Gateway function for connecting internet and sensor network: In unconstrained internet, we apply HTTP and TCP in the application and transportation layer, and apply IPv4/IPv6 in the network layer; while in constrained sensor network, we apply IETF CoAP and UDP in the Application and Transportation layer, and apply IPv6/IETF 6LoWPAN in the Network layer.

(2) Function for Ad-hoc networks: In the research and development of mobile ad-hoc networks (MANETs), vehicular ad-hoc networks (VANETs) have been studied in the framework of Intelligent Transportation System (ITS). In some other cases the vehicle (or a balloon, or a drone) could be equipped with communication device, and it could act as a communication station to form a MANET with other WMN AP. Directional antennas should be applied for extending IEEE 802.11s transmission range, and solar panels should be installed on the mobile AP for power charging.[17-23]

c. Monitoring Device: Three kinds of devices could be applied for tracking under such wildlife study conditions: mobile communication (GSM) based tracker (G-tracker), wireless communication based tracker (W-tracker), and satellite communication based tracker (S-tracker). Besides the device components (software, hardware, sensing, and communication), resource saving mechanism is necessary since a unit may work for more than 1 year for acquiring consecutive monitoring data. Standardization is important for the monitoring unit. For communication, in Physical layer, we could apply IEEE 802.15.4-2006; in MAC layer, we could apply IEEE 802.15.4e, low power IEEE 802.11; in Network layer, we could apply IETF RPL and IETF 6LoWPAN. For system control, we could apply IEEE 1888 series standards.[17-20]

c. Wildlife tracking: A tracker with a satellite positioning receiver sends the location data to the data center through cellular network or IEEE 802.16., when the tracker is within the effective communication area. Mobile AP (drone, balloon, vehicle, etc.) could be applied to relay the data when the tracker is out of the communication area. The behavior recognition unit with acceleration and gyro sensors could be installed in the tracker. Cellular and capillary communications could be integrated in this scenario. There are many IOT research issues on communication topics such as WSN, WMN, Mobile Communication, next generation internet, cloud service, etc.[13-16, 22-26]

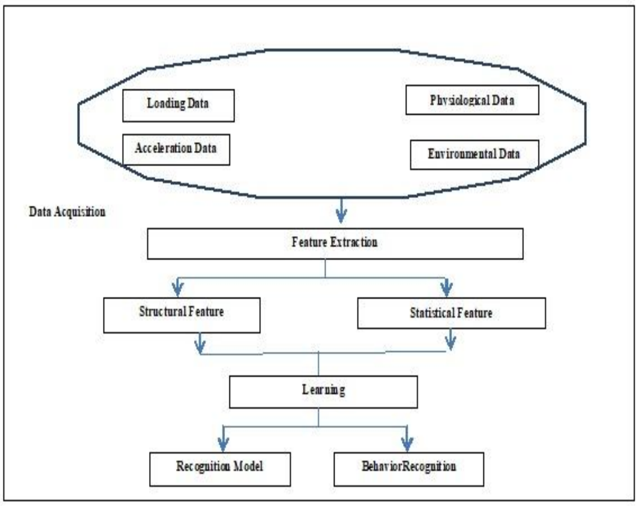

Figure 3: Behavior recognition process.

d. Output: In many wild areas, there are few mobile communication base stations, so Location Based Service (LBS) doesn't work efficiently, and the main localization method is satellite positioning system. Figure 4 shows behavior recognition process. Feature extraction is performed on the base of the acquired location, motion, environment, and physiological data. Behavior recognition and recognition model could be concluded on the base of the learning from structural and statistics features.[20-24]

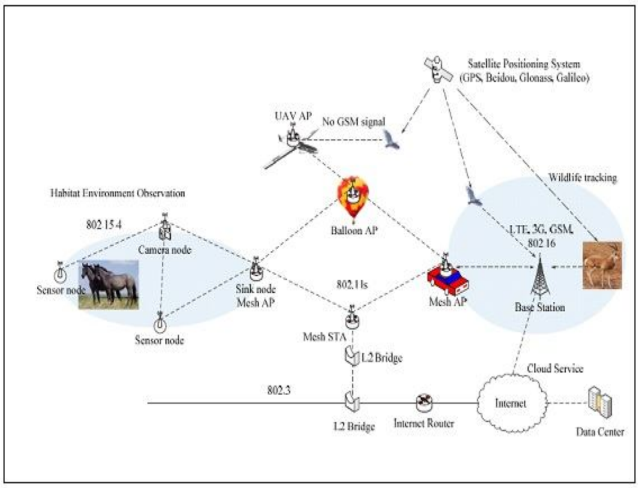

Figure 4: Graphical representation showing IOT arrangements for wildlife monitoring.

e. Checklist for undergoing wildlife tracking: If we have started the research and practical implementation on IOT platform for wildlife monitoring for 1 year, the aim of the preliminary research is to develop an effective monitoring unit for tracking and behavior recognition. The device power and memory are limited, so resource saving mechanism is an important issue. MCU rest and activation, local data computation and integration, data storage, effective data transmission and communication area indication, are the mechanisms one need to be concerned about in order to promote system's working efficiency. The cooperation of these four mechanisms is must for active working:

(1) For MCU rest and activation, usually a timer is used to wake up MCU in a certain cycle. For some research applications however, the MCU can be made to wake up according to the wildlife's behavior status.

(2) For local data computation and integration, the MCU analyze the positioning and sense data. Since some data amount is very big, so it takes more power during transmission. For example, the MCU performs behavior recognition on the base of the acceleration and gyro data, and only stores behavior data in the memory.

(3) For data storage, the memory may get overflowed if the positioning and sensing data increasingly stored in the memory before transmission. Data should be separated by the status and feature. For example, when the wildlife moves from "resting" to "flying", the data should be defined as "important" data.

(4) The new data replaces the "unimportant" data when the memory is overflowed. Coding algorithm and processing could also be applied.[22-28]

Present and further scope: IoT will definitely be a better option for the wildlife ecological and behavioral research programmers and users. IoT is still growing continuously, incorporation many new features on daily basis, finding new users and replacing old traditional methods used for the similar type of studies and events. Presently it is possible to study various ecosystems with much accuracy and clarity. This may help the researcher to get something more meaningful, which will definitely improve and enhance the knowledge of society about something unexplored. Such development and thought can also help in further modification of existing system, addition of some new features to the existing ones.[1, 2, 11, 26-32]

CONCLUSION: We observe an increasing requirement on ease of use of networks and services while maintaining privacy, and a proliferating number of "endpoints" including sensor clouds and of new networks types, such as vehicular networks. To solve the ensuing problems, this paper has proposed using identities, more precisely virtual identities, as representations of entities of all kinds as the endpoints of communication. It also proposes using digital shadows that represent projections of the entities involved in a communication use or in sessions. The handling of the privacy of data in the network and the infrastructure will be one of the vital issues to solve, as the temporary collection of session data is a potential asset that can be exploited. Future work will need to ensure that privacy needs of users and governmental requirements on handling data are met. The increased ease of use and improved flexibility to support new services and means of access in a dynamic and collaborative environment must be matched with an increased support for privacy protection if the solution is to be accepted.

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