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Design Issues and Considerations for Hardware Implementation of Wildlife Surveillance System: A Review

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ABSTRACT

Wildlife is a very important treasure in our daily life due to the significant impact of their existence to bring balance to our earth ecosystem. Today, an efficient wildlife surveillance system required by the world due to the extinction of wildlife. This paper describes a comprehensive overview of existing technologies developed for wildlife surveillance systems based on the depth analysis of the requirement and challenges in the current system. Specifically, five (5) main components of wildlife surveillance systems including data capture, power source, system controller, data storage and data transmission to the user are analysed and summarised. This paper will be able to assist researcher for the future works to enhance the development of wildlife surveillance system especially in the hardware platform.
Keywords: Wildlife, wildlife surveillance system, hardware

1. Introduction

Untamed species including all plants, fungi, and other organisms that grow or live wild in an area that is not familiarised by humans are classified as wildlife [1]. As a part of earth living, wildlife also plays a major role to sustain biodiversity in the earth ecosystem, while humans play a tremendous role in the extinction of wildlife through wildlife crime and wildlife habitat loss. Wildlife crime is the illegal taking, trading, exploiting, possessing, or killing of animals or plants in contravention of national or international laws [2] and many wildlife habitat loss due to human exploitation for making building, farming, roads and industrial development.

Nowadays, the problem of wildlife is if it is not taken seriously will lead to extinction living in history. World wide fund for nature (WWF) from the Living Planet Report 2018 states that the global living planet index (LPI) shows a 60 percent overall decline in the population of birds, fish, mammals, amphibians and reptiles between 1970 and 2014 [3]. To illustrate the criticality of this issue, the international union for conservation of nature (IUCN) categorised threatened wildlife into seven (7) categories: least concern; near threatened; vulnerable; endangered; critically endangered; extinct in the wild; and extinct [4].

We are in the situation with our planet endangered species are vanishing at a very fast rate. Every day, humans are hunting them for money. Many endangered animals are slaughtered for their body parts, cruelly killed for the trade and loss their habitat because of humans. For example, an elephant is killed for the ivory, rhinos are killed for horns, tigers are extinct due to poaching activity and habitat loss, sea turtles are slain for their eggs, shells and meat to make a variety of human consumer products, reptiles and exotic birds are sold as pets where many die in capture and transit, bears are poached for gallbladders and paws, paddlefish and sturgeon for food, beauty products and fashion, pangolin for the meat, scales and skin, coral used for aquariums, jewellery and picture frame and even native plants are poached from the wild [5]–[7].

To solve this problem, a wildlife surveillance system (WSS) plays a major role in monitor, tracking, security and collect data on the field to make comprehensive and holistic planning toward wildlife conservation. There is a huge gap to improve the current WSS technology because the implementation of WSS confronting a lot of parameters due to the location of WSS located in the wild field. In the wild field, researchers deal with a large area to be covered, no power source, high-risk situation for humans, climate factor, poacher and also target wildlife that always moving.

Figure 1. The current system uses a trap camera [8]

Current equipment of WSS used as shown in Figure 1 is unfit for the purpose since the system units were unable to provide near-live reporting and as they are unconcealable, they are often stolen [9]–[11]. These factors combine to make the challenge of protecting wildlife very difficult for those involved. This is very human-based and required a high human skill to be implemented. There are a lot of hardware aspects involved to design a good WSS to monitor or tracking the wildlife. In this paper, important issues are tabulated in Table 3 and five (5) main components of design issues and considerations such as data capture, power source, system controller, data storage and data transmission to the user are explained in the Section 3. This is to assist the reader in this area to easily catch up on the issues and further research to enhance the current WSS.

The rest of the paper is organised as follows. The related works of WSS implementation are presented in the next section. The WSS hardware design issues and considerations that consist of the five (5) important components of WSS are explained in the third section. Suggested research opportunities are addressed in the fourth section. Finally, concluding remarks is given in the final section.

2. WSS Implementations

To portray the importance of this research, the literature review shows that this topic is still immature and further research needs to be explored. It is reported that the WSS platforms have been evolved from manual human-based where the researcher needs to go into the field to the development of technologies that equipped with electrical and electronic components such as an embedded system, camera, sensors and advanced communication technology. To further understand the requirements as well as the latest hardware platform and technology being developed in this study, a spectrum of the issues is depicted in Figure 2.

According to [11], the time-lapse video concept acts as an important tool for collecting data on avian nest activity. The video system is the combination of the black and white infrared camera, an intelligent 12V direct current (DC) 960hour time-lapse recorder and a 12V deep cycle battery for the power. The 12V deep cycle battery with 200Ah can power the system for an average of 68 hours. To enable the system to monitor the nest for 24 hours per day, integrated infrared light-emitting diodes (LED's) is used because it manages to emit illumination at the low light level. The system also buried two (2) to three (3) cm under the sand to minimise the operating temperature. The camera was connected to a recorder via 18.3m, radio corporation of America (RCA) audio/video and power cable.

The development of a remote trip camera for the system report on a mammal survey in southwest China is proposed in [12]. The camera equips with an infrared sensor, built-in flash and autofocus features. The advantage of this system is it can differentiate the animal species. The method of differentiation is by using a sensor that can detect the heat profile of a cone-shaped area and is triggered by abrupt changes in temperature through the cone. The disadvantage of this system is the sensor sensitivity that is reliant on the temperature difference between the animal and the environment and battery power. The data was collected as part of patrolling duties.

Wildlife monitoring system based on digital single-lens reflex (DSLR) is proposed in [10]. The DSLR was protected with a weatherproof case to make it can cope with the wild condition. Texas Instruments MSP430 central processing unit (CPU) acts as a camera controller with custom software that performs all operations of the camera. By using the controller, the camera can be programmed to take an image at any specific minute in a year. In terms of power, the system uses the battery and solar panel to longer the operating hour. The power consumption analysis shows that the system required only a modest battery and solar panel combination of 12V, 2.5 hours battery and 5W solar panel to enable the system can take 10 images a day for 160 days a year.

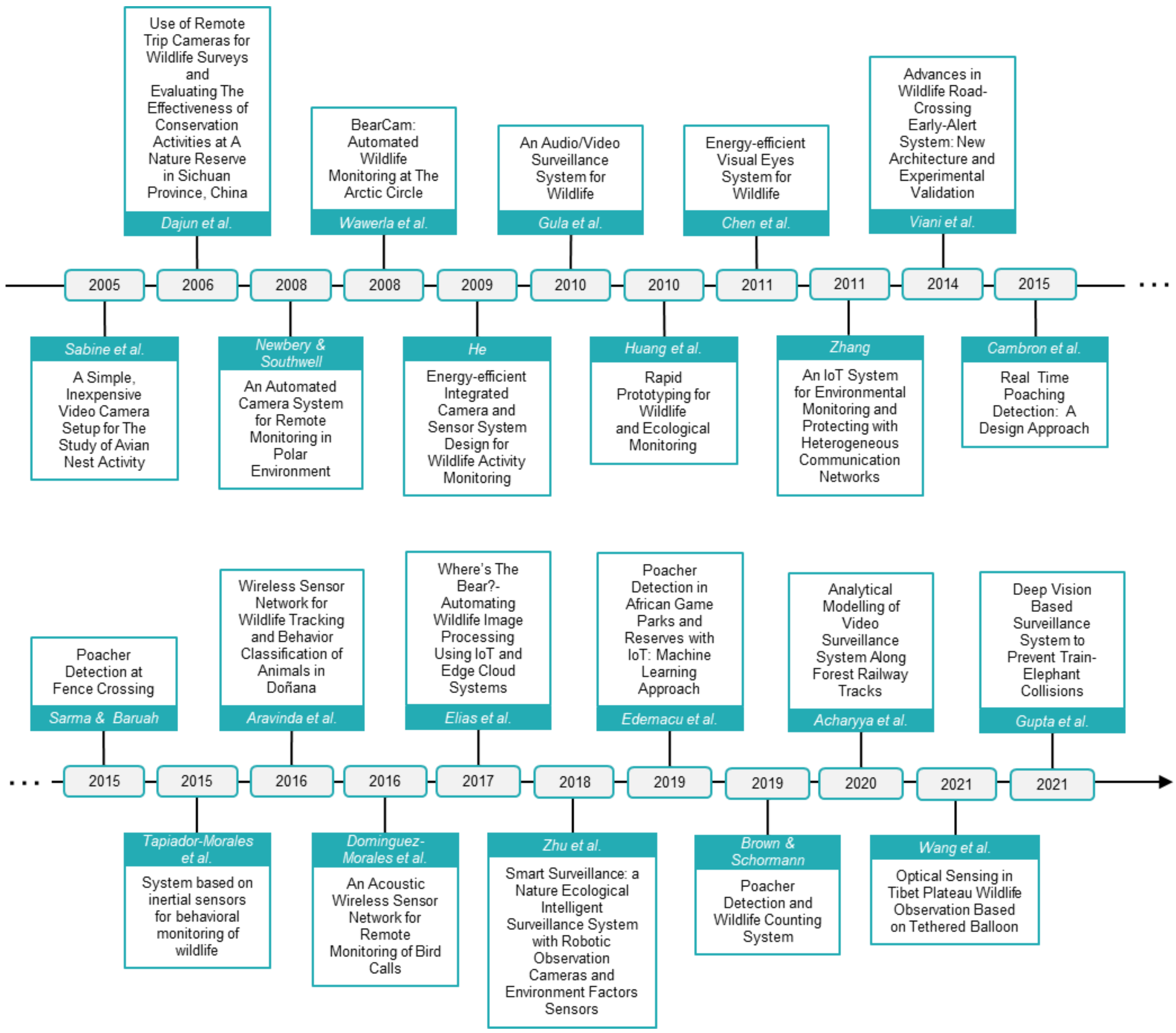

Figure 2. Spectrum of issues in wildlife surveillance system from 2005 to 2019

In [13], the BearCam that automatically detecting bears in the video captured with a "motion shapelet" algorithm is introduced. The system is divided into two (2) main parts. The first part is the remotely deployed camera and the second part is the base station placed in the main hut for the wildlife monitoring area. Radio with a 2.4GHz signal is used to transmit the video signal to the base station. At the base station, the radio signal is encoded by the motion picture experts group layer-2 (MPEG-2) encoder and stored on the portable hard drive. There are six (6) hard drives where each of them holds 230GB of data that can store 600 hours of video. The system is powered by a standard 12V, 33Ah lead-acid battery that can power a camera minimum for 24 hours. The connection of this BearCam monitoring system is as depicted in Figure 3.

A combination of video and sensor systems, called DeerCam is proposed in [9]. The main system that is mounted on the animals operate by the Intel PXA255 XScale microprocessor and is connected with a USB camera to capture video. The video data was compressed by an energy-efficient motion picture experts group layer-4 (MPEG-4) video encoder and temporarily stored in the 4GB compact flash (CF) card. The other part of the system is the deployment of several wireless routers close to the place animal always visits like a food station. When the animals come inside the radius of the communication range of the router, the wireless transmission module will upload the video data to a router and clean the storage. Besides video data, the DeerCam sensor system is equipped with an accelerometer, global positioning system (GPS), temperature and light sensors to gather many aspects of information about animal activity in the field.

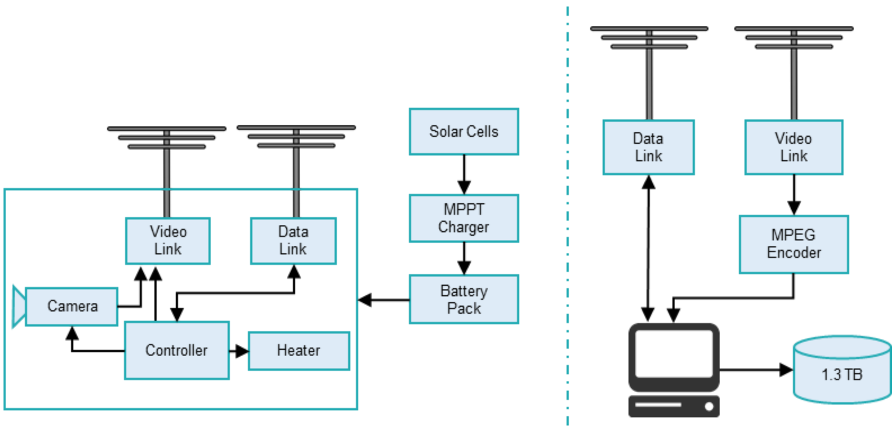

Figure 3. BearCam block diagram [13]

A system that can monitor bird species in the tropical rainforests of New Caledonia is addressed in [14]. The system is built up with a combination of the infrared surveillance camera, mini microphones for the audio, portable digital video recorders and the system powered by 25kg deep-cycle lead-acid batteries with a storage capacity of 100Ah. The system implementation was able to record the longest period for 58 days. The video recorded is stored in Archos 504 DVRs and Archos 700 DVRs with a capacity of 80GB and 100GB. The system camera is equipped with 12 infrared LEDs to make it can also record night vision.

EcoNet system with GPS sensor nodes carried by wildlife is executed in [15]. The base station with the Internet enables is deployed at the point that is normally visited by wildlife. The data communication network using store-carryand-forward fashion where device mounted on the animal is client devices that activate automatically when two (2) tracking devices are in radius. Inter/intra species encounters are recorded by the EcoNet system and then upload the recorded data to the base station deployed on the tree. By using a wide coverage communication network (3G/GPRS) the data then be uploaded to the Internet or retrieved by message periodically.

In [16], recommended a low power consumption image transmission system called an energy-efficient visual eyes system for wildlife. The system builds using the MSP430 microcontroller, field programmable gate array (FPGA) circuit, digital camera, solar-powered battery and general packet radio service (GPRS) modem. The MSP430 act as a brain that ensures all operating sequence. The FPGA circuit plays an important role to control the digital camera and the photoresistor for the brightness detection to able the system can detect the environmental brightness to change exposure time to snap a good quality photo. The image then transmits to the microcontroller via the RS232 interface. The system is also attached with GPS that can help the user to receive the exact location on the deployed system and can provide the time detection.

Wildlife monitoring system with an Internet of things (IoT) system was explained in [17]. The communication network of the system is based on three (3) different communication networks that support the protocol of IEEE 802.15.4/ZigBee networks, IEEE 802.11b WLANs and 3G respectively. By using different types of communication networks, the system design works with three (3) types of nodes as shown in Table 1. The first type of node using the High-Performance Node (HPN) that equip with the 3G router and Wi-Fi module that can obtain the connection between wireless wide area networks (WWAN) and wireless metropolitan area networks (WMAN). The second type of node using the Medium-Performance Node (MPN) includes the Wi-Fi module and ZigBee transceiver that can connect WMAN to wireless local area networks (WLAN) and the third type of node is the Low-Power Node (LPN) that only contains the ZigBee transceiver to deal with the short-range communication network. With various types of communication networks, the system is designed to become more flexible to suit the environmental condition comprised of network coverage, power consumption and distance.

Table 1. Three (3) different communication networks [17]

Type of nodes	Communication networks
High-Performance Node (HPN)	3G router and Wi-Fi module
Medium-Performance Node (MPN)	Wi-Fi module and ZigBee transceiver
Low-Power Node (LPN)	ZigBee transceiver

Doppler radar sensors integrated with wireless sensor network (WSN) are assembled for the wildlife road crossing detection is proposed in [18]. The system approach is by alerting the drivers by activating the light signal when the dangerous situation was recognised to avoid wildlife-vehicle collisions. The wireless node is equipped with low-cost Doppler radar installed along the roadsides. The Doppler radar can detect and identify the wildlife movement in realtime. In real-time, fast warning messages are then transmitted to the base station using a multi-hop wireless connection to warn the driver and to record for road crossing risk zones statistical analysis.

In South Africa, the development of sensors to detect poachers as they cross the fence line is explained in [19]. An infrared laser trip curtain is used to detect any person passing through the fence and when the person is in the restricted area, it will be detected using a cell phone detector. The detected poacher will notify the authorities using the XBee wireless network. This method is more about preventing poaching activities by detecting the poachers that commonly use phone devices.

In 2015, a system to detect poaching activity in a forest was designed using acoustic sensors in [20]. By using the acoustic sensor, the system can differentiate between a gunshot and other sounds. If the system detects sound intensity over the limit of the threshold level, it will transmit the sound to the computer module to analyse using the digital signal processing technique in MATLAB software and compare it with database frequency to conclude it is a gunshot or not. If the computer detects a gunshot, then an alarm is triggered to alert the forest security forces.

In [21], the wildlife monitoring system using a sensor fusion algorithm is proposed to checking animal correct behaviour in pitch, roll and yaw is proposed. The system hardware is made up of ARM-CortexM4 as a microcontroller, inertial measurement unit that equipped with three (3) sensors: accelerometer, magnetometer and gyroscope as the input data, using ZigBee as wireless data transfer, a memory card to store data and also an external battery. According to this paper, the sensor fusion algorithm is proved to improves both precision and noise interference on wireless data transfer using ZigBee. WSS proposed in this research is a sensor-based system that integrated many sensors as their input.

Animal tracking and behaviour classification such as feeding, sleeping, walking, jogging and running are discussed in [22]. By using the concept of WSN, the system is divided into three main parts which are collars on the animal, mote as a router and a base station to receive all the data from the sensor attached to the animal. Inertial sensor with other sensors like temperature, heart rate and GPS are combined as input data to classify animal behaviour. The data have been transferred from collars to the mote and from the mote to the base station using ZigBee. On the base station, the data process and transfer using Wi-Fi to the server. All the systems are successfully done in real-time mode.

The acoustic-based wildlife monitoring with WSN is explained in [23]. In the acoustic perspective, the audio frequency analyses differentiate between different types of birds. Microphone and sound card are used as an input device and analyse the frequency using Raspberry Pi and transfer using ZigBee by utilising WSN mesh network topology. With the application purpose to monitor the birds, an acoustic signal is a successful approach where the system is capable to run in real-time and can analyse the signal.

Wildlife image processing to classify animals in images is described in [24]. The system calls where's the bear (WTB) using motion-triggered camera traps and connect using Wi-Fi to the cloud for storage. The system with neural network training for animal recognition can be classified between bears, deers, coyotes and empty images. This is to avoid unnecessary image transfer, waste of bandwidth and save memory and power.

Nature ecological intelligent surveillance (EIS) system with robotic observation cameras and environment factors sensors is explained in [25]. EIS has been proposed equipped with robotic pan-tilt-zoom observation cameras that can detect and track wildlife sequentially in the field. The system also can effectively and constantly monitor the field environment and climate change through multiple sensors such as wind speed and direction sensors, temperature and humidity sensors and particulate matter (pm2.5) concentration sensors. There are solar panels that served as a power supply system that kept the power stable and overall system using Wi-Fi as a wireless data transmission platform.

IoT framework comprises of image capturing nodes deployed in game parks and reserves for capturing images after motions are detected is proposed in [26]. To cover the vast area of the park, the IoT framework architectures that comprise perception, network and application layer are implemented. The perception layer comprises sensor nodes and the network layer inter-connects the perception layer with the application layer and transmits data and information between the two layers with mobile communication technologies (2G, 3G, LTE and 5G) and IEEE 802.X (Wi-Fi and Zigbee). At the application layer, massive data received and analysed with the machine learning algorithm later can be visualised to the users via cloud storage. The captured images are also filtered by classification using a machine learning algorithm to improve the prediction accuracy of poacher detection and reduce the rate of false alerts notifications.

In [27], the system based on thermal imaging is proposed to differentiate between human dan animal. The aim is to increase efficiency of the ranger patrolling system. The experiment using thermal video input and utilised image processing and convolutional neural network (CNN) method can accurately classified between human and animal but less accurate between animals. The method approached using thermal imaging method claim to be low cost and efficient to detect poachers even at dark environment which usually unable to successfully detect by normal camera at night.

An improved real-time video surveillance system using analytical modelling is proposed in [28] to avoid accident happen between elephants, other animals and trains. Reported, this incident directly affects the forest ecology as almost 80 and 60 elephants died and injured cause by the railway track accident. By improving the analytical model of video surveillance, the right placement angle and position of the camera can be monitored. The analytical modelling proposed not even for the straight railways, but also for the sharp curve railway track. The system proposed can affectively detect present of wildlife and alert the workers to avoid accident happen.

An optical sensing using tethered balloon is explained in [29] to encounter inability operational of UAV monitoring method on the winter season with low temperature and strong wind. The project is divided into three main parts which is the tethered balloon system, stable platform for the camera and the infrared camera. The balloon using helium gas to lift up to the air and fixed by tethered cable. The stable platform specifically designed to have a stable observation and power and control using wire cable and optical fibre. The camera utilise infrared camera system equipped with FPGA for control and image processing. The project can work in harsh winter environment and can detect up to 2-5km distance.

Similar to [27], the method approached in [30] is to improved the current video surveillance system by enhance the video identification system to detect animal. In this system, deep vision using CNN and three (3) artificial intelligence transfer learning model are proposed. The CNN model tested to have accuracy of 99.81% and Inception Net of transfer learning model resulted the best with accuracy of 99.91%. Transfer learning models reportedly have better results as they are more layers and parameters.

There is a lot of research and invention in terms of wildlife monitoring, but there is always a limitation on some issues related to the type of device and hardware used to captured and monitored, the sensor device that should be used for detecting and signalling a changing condition in the forest, the data storage, recently data transferring (wireless) and also in term of power consumption due to absent of power source in the forest. To summarise these issues, important issues of WSS in related previous works are listed in Table 2.

Table 2. Importance issues in the WSS

Refs.	Hardware	Type of data				Data	Transmission	Power		Application
		V	I	A	S	Storage	Method	Source	Lifetime	
[11]	Infrared Camera, Lapse Recorder, Integrated Infrared LED	✔		✔		Tape	RCA audio/video cable (18.3m)	12V deep cycle battery	68h	To monitor avian (bird) nest activity
[12]	Remote-Trip Camera		✔		✔	Memory card	Manually collect	Battery	14 days	Monitor mammal population
[10]	Canon Eos-300d/Rebel XT DSLR Cameras, Texas Instruments MSP430 CPU		✔		✔	2GB memory card	Manually collect	12V battery & 5W solar panel	Everyday (only 10 photo/day)	Monitoring of Adeline Penguin
[13]	WV-CP484 Cameras, Solar Panel, 2.4Ghz Opteron Processor	✔		✔		230GB portable hard drives	Wireless 2.4GHz radio signal (500m)	12V battery lead acid	48h	To monitor the behaviour of bears at the arctic circle
[9]	USB Camera, 400Mhz Intel PXA255 Xscale Microprocessor, GPS, Temperature, Light Sensor	✔		✔	✔	4GB CF card	GPS, 802.11based wireless & ethernet cable	Battery	90 -120h	Monitor cross season behaviour of the animal
[14]	Infrared Illuminator Surveillance Camera Electret Mini Mic, Digital Video Recorder, DVR	✔		✔		100GB hard drives	6.4mm multicore coaxial cable	2 unit 12V deep cycle battery	12 days	Monitoring endemic bird species in the tropical rainforest of New Caledonia
[15]	Tracking Collars with GPS, WSN				✔	10kB memory	GPRS, Wi-Fi & radio	Battery	22h to 42h	Monitoring & tracking
[16]	MSP430 Microcontroller, FPGA, Digital Camera, General Packet Radio Service (GPRS) Modem, GPS		✔		✔	Internal memory	GPRS	Solar Powered Battery	Everyday (only 5 photo/day)	To monitor the migrant seabirds
[17]	Camera, Processor XScale PXA2771, MSP430 Microcontroller	✔	✔	✔	✔	Flash memory	ZigBee network, IEEE 802.11b WLAN & 3G	Solar Powered Battery	Unlimited	Monitor & protect wildlife
[19]	Cell Phone Detector, Infrared Laser Trip				✔	No memory	Xbee wireless	Battery	N/A	Anti-Poaching by detecting any phone use and crossing the fence
[20]	Acoustic Sensor				✔	No Memory	Xbee wireless	Battery	N/A	Anti-Poaching by detecting a gunshot

*V – video, I – image, A – audio, S – sensor

Table 2 (cont.). Importance issues in the WSS

Refs.	Hardware	Type of data				Data	Transmission	Power		Application
		V	I	A	S	Storage	Method	Source	Lifetime	
[21]	Inertial Sensor, accelerometer, magnetometer, gyroscope, ARM-CortexM4 microcontroller				✔	SD card	ZigBee & Wi-Fi	Battery	N/A	Wildlife monitoring using a sensor fusion algorithm

[22]	Inertial sensor, temperature sensor, heart rate sensor, GPS, microcontroller				✔	SD card on collars	ZigBee & Wi-Fi	Battery, solar cell	N/A	Wildlife behaviour classification
[23]	Raspberry Pi, Microphone, USB sound card			✔		N/A	ZigBee	Battery	N/A	Wildlife (bird) monitoring
[24]	Motion triggered camera traps		✔			Cloud Storage	Wi-Fi	Battery	N/A	On-site animal image classification
[25] ✔	Robotic pan-tilt-zoom cameras, wind speed & direction, temperature, humidity and pm2.5 concentration sensors	✔				120G SSD	Wi-Fi	Solar Powered Battery	N/A	Wildlife & climate changes in the forest
[26]	Camera, IoT network		✔			N/A	2G, 3G, LTE, 5G, Wi-F, Bluetooth, ZigBee,	Recharge able battery	N/A	Poacher Detection in African Game Parks
[27]	UAV, Thermal imaging	✔	✔			N/A	Manually collect	Battery	N/A	Differentiate human and animal to detect poacher
[28]	Video surveillance	✔				N/A	N/A	N/A	N/A	Analytical model and alert notification when detect wildlife
[29]	Tethered balloon, stable platform, infrared camera, FPGA	✔	✔			N/A	Optic cable	Cable	Hours	To monitor wildlife during winter
[30]	Video surveillance	✔	✔			N/A	N/A	N/A	N/A	Deep vision video surveillance

*V – video, I – image, A – audio, S – sensor

3. WSS Hardware: Design Issues & Consideration

The WSS generally focuses on monitoring and tracking wildlife that can be divided into two (2) main methods, static or dynamic WSS as shown in Figure 4. Static WSS is commonly mounted on the tree to monitor specific locations and angles. This method usually required a camera as the main data capture acts as an input device that captures images or video [31]. Image or video is massive data but provides clear information that the authority needed. Many image or video processing methods have been proposed to accommodate this matter [32]–[35]. Because it is static, data transmission send to the user method can either be manually collected from storage, wired or wireless.

While the WSS dynamic method refers to the WSS that is mounted on the animal itself to track the behaviour and location of the animal. GPS is common hardware that is attached as an input device for the WSS dynamic method [36], [37]. Because this method is mounted on the animal, it is a real concern about the weight ratio of the device via the body of the animal [38], [39]. This is one of the biggest challenges when using this method. The device must be able to be carried comfortably and does not harm the animal.

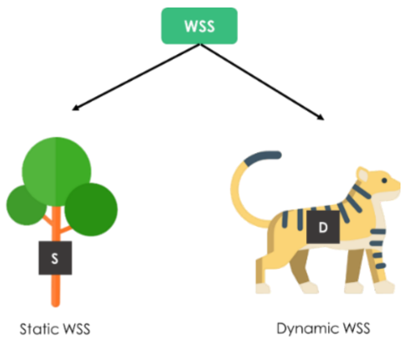

Figure 4. Normal position of static versus dynamic WSS

Taking into consideration of static or dynamic methods and requirements to solve the problem in the wild field, there are five (5) main components of WSS hardware design issues which are data capture, power source, system controller, data storage and data transmission to the user as shown in Figure 5.

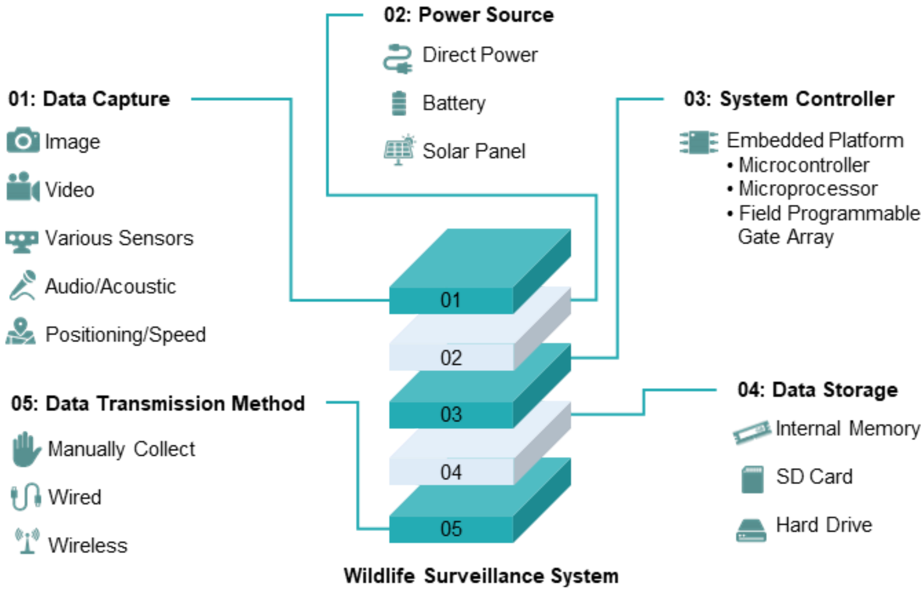

Figure 5. Five (5) main components of WSS

The data capture can equip with a camera and various sensors to collect sensing data required by the user. As we know, in the wildlife field there is not easy to have direct power, hence it is very challenging in terms of power consumption. The system can either use direct power for a short distance but in most cases, it required batteries as the power source and support by the solar panel to increase the operating hours. It is also important to have an efficient system controller that is often an embedded platform such as a microcontroller or microprocessor. The data capture also required data storage that can be stored in either internal memory, SD card or hard drive. Finally, the stored data can reach the user or authority by manually collect from the storage or just receive in the base station using wired or wireless transmission. Mostly the combination of these five (5) components is required to build a complete WSS. Each component is further explained in the following subsection.

3.1 Data Capture of WSS

The data capture is a signal received from the sensor attached to the system. Various types of sensors such as a camera to capture images and video, a microphone to record the audio and acoustic generate by the animals, a GPS for trekking and positioning and also various types of sensors like temperature, humidity and brightness sensor. Each sensor or camera attached to the system depends on the method of monitoring either static or dynamic. The sensor fusion method is also being utilised to advance the system capability to monitor the wildlife.

3.2 Power Source of WSS

Power is the biggest constraint for the WSS that build up from electronic components that using power for every second to operate. Most of the systems is using the battery as the main power because it is portable, but the problem is the lifetime is short [38], [40]–[42]. It is very important for the WSS to have long operation hours because the system will deploy in the wild area to monitor the wildlife and required a long period. Hence, an ultra-low-power system is required [38], as the system developed must consume minimum power and be efficient. An alternative to this problem, some researchers using a solar panel to support the batteries and make the operation hour of the system become much longer [10], [16], [17], [43].

3.3 System Controller of WSS

System controller based on the embedded platform is the most important part of WSS that control the entire running operation, however, from the previous work, this component did not deeply discuss in term of advantage and disadvantage on the development of WSS. The controller plays a major role to perform automation control of the system for collecting sensing data, simplifying data processing and networking of the system. From the previous work, the common system controller used is shown in Table 3.

Table 3. The system controller of WSS

References	Embedded Platform		
	Microcontroller	**Microprocessor**	**FPGA**
[10]	✔		
[13]	✔	✔	
[9]		✔	
[16]	✔		✔
[17]	✔	✔	
[18]	✔		
[20]	✔		
[21]	✔		
[22]	✔		
[23]		✔	
[25]		✔	
[26]	✔	✔	
[29]			✔

The embedded platform, which is an electronic device, always concern with power efficiency which is one of the most concerning factors in the development of WSS. Based on Table 3, the microcontroller is the most embedded system used because of the non-complex programming and due to the low energy and low cost compare with the microprocessor. However, the microcontrollers have limitations because it only can perform sequential operations that makes it cannot perform complex tasks like image processing.

In [13], the system using both microprocessors and microcontrollers on different parts of the project. The microcontroller is used as an on-site device to process less complex tasks like regulates the temperature, monitors the supply voltage, protects the batteries from over-discharge and sends video data to the base station. The microprocessor is only used in the base station to perform the image processing to detect the bear with no power issued. Two (2) embedded platforms that are MSP430 microcontroller and FPGA also been used in [16]. The system also concerns about energy consumption by always put the system on standby mode control by the microcontroller that using less energy and only activate the FPGA board when to capture and transmit the image.

3.4 Data Storage of WSS

Instead of being directly transferred to the base station, the data is also still being stored in the memory on the site. High memory capacity is required to store more quality input data such as images or videos that are very massive. In [13], [14], the system preferred to use portable hard drives that have high memory capacity compared to the other system that only used a memory card. However, currently due to the increase of memory card capacity that can up to 512 gigabytes [44], it has been a most selected memory device that offers the advantages of small shape and lightweight devices.

3.5 Data Transmission to User of WSS

WSS data transmission consists of three (3) methods which are manually collect directly from the memory device, wired, and wireless. The latest technology is the wireless method due to the constraint of another two (2) methods that are time-consuming and human-based by manually collect from the storage and wired weaknesses are unable to cover a large area and impractical in some locations like in the jungle. Although using wireless is the best technology, there is also have a limitation in terms of the quality of data transmission via distance.

WSN is the latest method used to covered and capture data with long-range and large areas. A sensors network is an integration of multiples sensors in a system to collect information about different environment variables [21] while WSN using a node concept that can transfer data of the sensor from one node to another node until the data reach the end node. Star, tree and mesh are three (3) types of WSN topology that are application dependent. The resources, cost and environment are among the factors considered in adopting a suitable topology [40], [45]. Figure 6 shows the three (3) types of WSN topology structure.

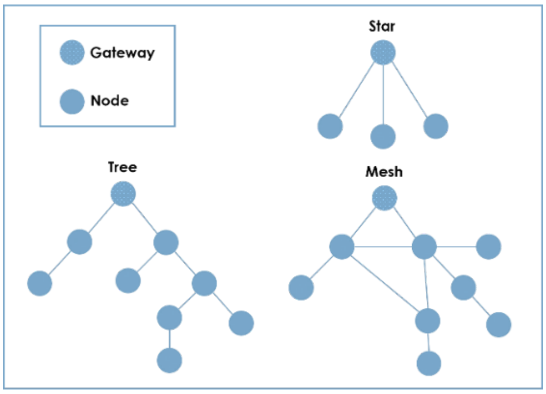

Figure 6. WSN topology

4. Research Opportunities

Currently, based on the five (5) main components of WSS, there is remains a huge gap to be further explored to design a WSS. To date, the conventional system is still very human-based which required the authorities in charge is an expert in the field of wildlife to detect if there is any existence of animal or poaching activities in the forest. There are five (5) major research opportunities that can be identified as follows:

1. conventional systems required an expert in the field of wildlife in which these skills are subjective and may be different from one to another worker. A standard system that will detect the sign of animals or humans in terms of motion, image and video records should be proposed;

2. most conventional systems are not in real-time where all captured data were only stored into a memory card and later to be downloaded manually by the officer on duty during the visit;

3. Sensor fusion should be further explored as it can provide more comprehensive input data especially for wildlife behaviour and tracking and can be benefited as data fusion;

4. power efficiency in terms of sensor, controller and data transmission is really crucial to ensure the system can sustain inadequate time in the wild field; and

5. the efficient data storage in terms of data compression computation and transmission topology should be explored.

5. Conclusion

It is the ultimate aim of the research work presented in this paper to address design issues and consideration for hardware implementation of WSS based on the limitations presented in the previous works. The important issues have been tabulated in Table 3 to assist readers with the hardware design. The five (5) main components of data capture, power source, system controller, data storage and data transmission to the user have been highlighted and explained. Moreover, the research opportunities for the researcher in this area are suggested to be further explored. Last but not least, wildlife that grows on our earth is really important not only today but for our future generations.

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