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An investigation into the viability of a new generation wildlife tracking system

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Abstract

Wildlife management and conservation is becoming more important by the day. Recent advances in the world of wireless communications opened up new possibilities for wildlife tracking which have never been researched in detail before. Using the positioning capabilities of GPS and the communication capabilities of GSM networks as basis for wildlife tracking enables a level of efficiency, flexibility and cost-effectiveness that cannot be matched by the earlier approaches. The aim of this study was to determine if a new generation wildlife tracking system based on a combination of GPS/GSM technology will offer numerous advantages above existing technologies. From discussions with different participants in this market it became evident that the local market leader was an existing commercial player, Africa Wildlife Tracking (AWT), specializing in the conventional tracking methods described earlier. Interviews were conducted with AWT as well as the following categories of end-users: Private game farm owners, wildlife researchers, national parks and endangered wildlife organizations. According to the interviews a user requirement statement was compiled by combining the requirements of wildlife researchers with the few additional requirements for wildlife management. In Chapter three possible positioning, data transfer and distribution technologies were evaluated against the user requirement statement in Chapter two (2.3). In Chapter four a system has been defined to meet the market needs as described in chapter two using the technologies as described in chapter three. Chapter five describes how the prototype system based on the design described in the previous chapter was deployed in the field to enable the practical assessment of how this system would perform in typical application environments. Based on this practical feedback, the key research question could be answered: Will a new generation wildlife tracking system based on a combination of GPS/GSM technology be a viable option in the practical management of wildlife conservation establishments? In Chapter six the tracking system was evaluated by analysing the data received from devices already deployed. Futhermore the success of the system was stated by evaluating the main features and requirements of the system using feedback from the market as published in the media. From this study it is clear that a new generation wildlife tracking system based on a combination of GPS/GSM technology will be a vaible option for the tracking and management of wildlife. The development of this tracking concept and the implementation of the

technology stretched over a period of more than three years, with the first tracking collar employed during 2002. By the time this thesis was concluded, over 300 units were successfully deployed on various animals including baboons, crocodiles, wild dogs, hyenas, leopards, cheetahs, lions, buffallo, sables, rhinos and elephants. These applications of the technology spans across South Africa and other countries such as Botswana, Costa Rica, Zambia and Kenya.

Samevatting

Wildbestuur en –bewaring word toenemend belangrik. Vooruitgang in die gebied van draadlose kommunikasie tegnologie, het gelei tot nuwe moontlikhede met betrekking tot wildnasporing. Deur gebruik te maak van GPS as posisionerings tegnologie en GSM as kommunikasie tegnologie is 'n vlak van effektiwiteit, aanpasbaarheid asook koste-effektiwiteit moontlik wat nog nooit deur vorige benaderings bereik kon word nie. Die doel van hierdie studie was om te bepaal of 'n wildnasporingseenheid, gebaseer op 'n kombinasie van GPS en GSM tegnologie, voordele bied bo bestaande tegnologie. Dit het duidelik geword uit marknavosing dat Africa Wildlife Tracking (AWT) 'n belangrike rol speel in die wildnasporingsmark. Onderhoude is gevoer met laasgenoemde, sowel as met eienaars van private wildplase, navorsers, nasionale parke asook beskermde wild organisasies. Uit hierdie onderhoude is gebruikerspesifikasies ontwikkel deur die spesifikasies van navorsers te kombineer met addisionele spesifikasies vir wildplaasbestuur. In hoofstuk drie is die moontlike posisionerings, data oordrag en verspreidings tegnologieë geevalueer teen die gebruikerspesifikasies in hoofstuk 2 (2.3). Hoofstuk 4 definieer 'n sisteem volgens die gebruikerspesifikasies in hoofstuk twee en die tegnolgie beskryf in hoofstuk drie. Prototipes van die nasporingsisteem is in die veld getoets om die doeltreffendheid van hierdie sisteem te bepaal, gebaseer op die terugvoer kon die navorsingsvraag beantwoord word. Dit is duidelik uit hierdie studie dat GPS/GSM tegnologie wel voordelig kan wees vir wildnasporing en wildbestuur. Die ontwikkeling en implementering van die tegnologie strek oor 'n tydperk van meer as drie jaar, met die eerste nasporingsband wat gedurende 2002 ontplooi is. Aan die einde van hierdie tesis is daar reeds meer as 300 eenhede suksesvol ontplooi op 'n verskeidenheid wilde diere insluitende bobbejane, krokodille, wildehonde, hyenas, luiperds, jagluiperds, leeus, buffels, renosters, swartwitpense asook olifante. Die aanwending van hierdie tegnologie strek oor Suid-Afrika asook lande soos Botswana, Costa Rica, Cameroon, Zambië en Kenia.

Glossary

Animal Tracking

GSM (Global System for Mobile communication)

GPS (Global positioning system)

VHF (Very high frequency)

Wildlife management

Game reserves

Nature Conservation

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List of abbreviations

GPS	Global positioning system
GSM	Global System for Mobile communication
GPRS	Global packetswitched radio service
VHF	Very high frequency
PC	Personal computer
SMS	Short message service
E-MAIL	Electronic mail

Chapter 1

Problem statement, aim of this study and literature overview

Chapter one

1 Problem statement, aim of this study and literature overview

1.1 Introduction

The wildlife tracking market can be regarded as a niche market in the worldwide radio frequency (RF) tracking industry. The primary method of wildlife tracking till recently was based on an RF beacon transmitter fitted to the animal and a mobile manually operated tracking device that is equipped with a RF receiver. This method of tracking is very time consuming, as the animal is tracked by physically searching for it in the veld, which mostly limits the tracker to focus on one animal at a time. Another method that found limited use in wildlife tracking is GPS positioning combined with communication by means of satellite telemetry. This method of tracking is very expensive, the physical size of the tracking device limits the usage of this system to large animals such as elephants, and there are to date not an efficient power source to drive this system for a desired period of time without putting undesired stress on the animal.

Recent advances in the world of wireless communications resulted in the widespread use of RF tracking based on mobile transceivers that communicate not with a mobile tracking device or with satellites but with the beacons of a fixed installed wireless network. The main fields of application in the world tracking market for this approach to tracking are found in asset tracking, vehicle tracking and shipment tracking. The mainprimary method of positional tracking used in this industry is GPS location based on triangulation, with data communication by means of GSM, satellites and or an alternative network of fixed RF transmitters.

The above developments opened up new possibilities for wildlife tracking which have never been researched in detail before. Using the positioning capabilities of GPS and the communication capabilities of GSM networks as basis for wildlife tracking may enable a level of efficiency, flexibility and cost-effectiveness that cannot be matched by the earlier approaches. As this new approach to wildlife tracking has not been applied in practice before as an integrated part of wildlife management systems, the need existed to research the viability of a new generation wildlife tracking system based on a combination of GPS/GSM technology.

1.2 Problem statement

According to Gordon (2001) the understanding of factors determining the distribution and movements of animals around the world is a major objective for scientists, conservationists and natural resource managers. Developing this knowledge animal populations will be managed to meet conservation, sporting or natural heritage objectives. Scientists have long battled with the logistics of gathering information on the movement and distribution of individuals and populations, often relying on visual observation or VHF technology (Gordon, 2001). According to Theiss *et al.* (2005) researchers are always looking for new technology that will enable a quantum leap regarding the ability to study such an industry.

The studies of movements of free-ranging animals are commonly done with radio-telemetry, using very high frequency (VHF) transmitters attached to the animals. This method of tracking is expensive and time and manpower demanding (Rodgers, 2001a), and of variable accuracy (Licoppe & Lievens, 2001). This method of tracking is limited to a few daytime relocations per week, or per month (Rodgers, 2001a), resulting in large biases if animals use habitats differently depending on the time of day (Polamares & Delibes, 1992; Olson *et al.*, 1997, Gordon, 2001). This method of tracking is inadequate for estimating behaviour such as flight initiation distances, because direct observations are only possible in open areas (Olson *et al.*, 1997, Gordon, 2001).

Satellite telemetry is less accurate than either VHF tracking or GPS tracking. This method of tracking frequently reports locations of which the accuracy varies from within 150m to many kilometers (Keating *et al.*, 1991), approximately 90% of satellite-based location estimates are within 900m of the known location (Fancy *et al.*, 1989). Satellite telemetry is very expensive according to the Smithsonian institution (1998).

Global positioning system (GPS) tracking are likely to revolutionize animal telemetry studies (Rumble *et al.*, 2001). Tracking animals during nighttime or periods of bad weather, receiving data by remote transfer, collecting information about animals without disturbing them (Lindzey *et al.*, 2001, Rumble *et al.*, 2001), lowering operational and equipment costs, as well as gathering very accurate positioning information (Rush, 2000) are some of the benefits offered by GPS. The variety of GPS system configurations now available makes it possible to apply technology to most mammals and some large birds (Kliskey & Byrom, 2001). The greatest limitation to the universal use of GPS revolves around data retrieval (Hulbert, 2001). According to this researcher the most exciting development is the future integration of GPS with various radio technologies. Using the GSM network may provide a solution to data retrieval, especially on animals that can never be recaptured again (Hulbert, 2001).

The above-mentioned literature emphasizes the importance of research on the use of GPS/GSM technology for a new generation wildlife tracking system. At the commencement of this study, no comprehensive study has been published using this technology for wildlife tracking. The research question to be addressed is therefore defined as follows: Will a new generation wildlife tracking system based on a combination of GPS/GSM technology be a viable option in the practical management of wildlife conservation establishments? By answering this question it will become clear to what extent the advancement in technology will open up new dimensions for wildlife research.

1.3 Aim of this study:

The aim of this study is to determine if a new generation wildlife tracking system based on a combination of GPS/GSM technology will be a viable option in the practical management of wildlife conservation establishments in terms of

- the accuracy by which animals can be tracked without interfering with the normal behaviour of the animal;

- the costs involved in achieving this level of tracking accuracy;
- the general acceptability of this mode of tracking from the perspective of research and conservation specialists regarding ease of use and level of usefulness of the information that is gathered.

1.4 Hypothesis of this study:

A new generation wildlife tracking system based on a combination of GPS/GSM technology will be a viable option in the practical management of wildlife conservation establishments in terms of accuracy and costs involved. This mode of tracking will also be accepted by research and conservation specialists.

1.5 Structure of thesis

The thesis is structured as follows:

- Chapter one contains the problem statement, aims, hypothesis, literature study and structure of this study.
- Chapter two focus on the market needs and developing a user requirement statement for a wildlife tracking system that strives to achieve the stated objectives.
- Chapter three describes the technology survey that was conducted to identify a set of technologies that will be suitable on which to base a system for wildlife tracking. The different available positioning and communication technologies were evaluated in terms of the ability to satisfy the functional, form and fit requirements for a wildlife tracking system, and the most suitable technologies were selected.
- Chapter four discusses how the information collected in the previous chapter was translated into a conceptual system design that will enable researchers, wildlife and game park managers to track and monitor their animals more effectively with much less effort from a single point.
- Chapter five describes how the prototype system that was developed based on the design described in the previous chapter was deployed in the field to enable the practical assessment of how this system would perform in typical application environments. Based on this practical feedback, the key research question could

be answered whether the chosen set of technologies could support the effective tracking of animals to enable improved management of conservation establishments.

- Chapter six describes the evaluation of the market response to the prototype concept, and the conclusions of this study.

1.6 Literature study

1.6.1 Need for tracking

The growth of environmental awareness and public concern for wildlife that began in the 1980's has continued into the 21st century (Rodgers, 2001b). According to van Dyk (2003) the need to preserve our natural heritage is a very important aspect to mankind and wildlife all around the world. The understanding of factors determining the distribution and movements of animals around the landscape is a major objective for scientists, conservationists and natural resource managers (Gordon, 2001). It is only through developing this knowledge that animal populations will be managed to meet conservation, sporting or natural heritage objectives. Scientists have long battled with the logistics of gathering information on the movement and distribution of individuals and populations, often relying on visual observation or VHF technology to gather data (Gordon, 2001).

Increasing poaching pressure, shrinking habitats and struggling economies in African countries have led to a growing consensus amongst conservationists and international conservation organizations (Matzke & Nabane, 1996) that wildlife should be protected as an essential step towards growing ecotourism in these countries. Ecotourism is a rapidly growing industry, and developing nations are increasingly popular destinations for eco-tourists (Gössling, 1999, Thorstad *et al.*, 2004). According to Orams (2002) there are psychological, social and economic benefits experienced on the human side of the interaction, but a limited number of wildlife benefited as well. Tourists and management agencies have an obligation to carefully consider the impacts of tourism on wildlife. Greater attention needs to be paid to developing effective management strategies that are based upon knowledge and the precautionary principle (Orams, 2002).

Throughout history people have had a close relationship with animals; the idea of visiting and observing wild animals for recreational purposes, as a tourist attraction, has been a more recent phenomenon (Orams, 2002). Getting close to animals is an extremely popular mechanism whereby tourists can feel they are communing with nature; the range of opportunities for tourists to interact with wildlife continues to increase (Orams, 2002). The commercial sector is constantly looking for new ways to become more efficient and effective in their business. Researchers are always looking for new technology that will create a boom in the industry (Theiss *et al.*, 2005). Field craft has grown from a trapper's art into a biologist's science that has been enhanced by the advent of the most recent technology (Hulbert, 2001).

1.6.2 Technology used for tracking

A technical description on the technology used for tracking is covered in Chapter three (technology survey)

1.6.2.1 VHF-telemetry

According to Rodgers (2001a) the studies of movements of free-ranging animals are commonly done with radio-telemetry, using very high frequency (VHF) transmitters attached to the animals. The relocation of radio-collared large wide-ranging animals is usually done from a vehicle or plane, which is expensive and time and manpower demanding. The most radio-tracking studies of these animals are limited to a few daytime relocations per week, or per month (Rodgers, 2001a). This may result in large biases if animals use habitats differently depending on the time of day (Polamares & Delibes, 1992; Olson *et al.*, 1997, Gordon, 2001). This method of tracking is inadequate for estimating behavior such as flight initiation distances; direct observations are possible only in open areas (Olson *et al.*, 1997, Gordon, 2001). Traditional radio telemetry fixes are time consuming to collect and of variable accuracy (Licoppe & Lievens, 2001). According to van Dyk (2003) a leading researcher in the canine field (leopards, wild dogs, lions, cheetahs etc.) VHF radio tracking is laborious, frustrating and costly endeavor. He stated that the development of modern technology is providing the potential for more effective and reliable animal tracking, and may be able to cope with the increased demands for information.

1.6.2.2 Satellite tracking

Satellite tracking can only be used on large animals (eg.elephants) . The primary advantage of satellite tracking is the ability to track animals over long distances and in remote areas, it also minimizes researchers field time requirements. This method is less accurate than either VHF tracking or GPS tracking. The accuracy of reported locations frequently varies from within 150m to many kilometers (Keating *et al.*, 1991), approximately 90% of satellite-based location estimates are within 900m of the known location (Fancy *et al.*, 1989). According to the Smithsonian institution (1998) satellite telemetry is very expensive.

1.6.2.3 GPS tracking

Global positioning system (GPS) is likely to revolutionize animal telemetry studies according to Rumble *et al.* (2001). A GPS collar allows biologists to collect systematically scheduled data when VHF telemetry data is difficult or impossible to collect (Rumble *et al.*, 2001). The use of GPS aboard satellites for tracking can provide significant benefits to satellite operators. These benefits include potentially lower operational and equipment costs as well as enabling higher levels of satellite automation and providing very accurate positioning information (Rush, 2000). VHF-based–radio telemetry studies often yield biased movement data, because relocation schedules are influenced by daily light and weather patterns (Lindzey *et al.*, 2001). Also, the tracking of wide ranging animals often requires the use of costly, specially equipped aircrafts. GPS collars should provide locations of studying animals regardless of weather and daylight patterns and offer sufficient spatial coverage to provide accurate locations of most terrestrial mammals. Furthermore, the frequency of locations theoretically available from GPS collars should allow documentation of fine-grained movement patterns (Lindzey *et al.*, 2001). According to Moen *et al.* (1997) the GPS allows the researcher to obtain accurate data (within) 5 meters on animal location as frequently as every minute or as infrequently as once per week.

The size and weight of GPS units are a particular constraint that has meant that until very recently GPS tracking of an animal with a body weight of less than 20 kg has been difficult, and for animals weighing less than 10 kg impossible (Kliskey & Byrom, 2001). The variety of GPS system configurations now available to researchers makes it possible to apply technology to most resource selection studies of mammals and some large birds. As always, size of animal units and cost are the key issues that researchers must consider in selecting an appropriate system to meet their research objectives. Attention must also be given to operating life, accuracy of locations and sampling intensity (Rodgers, 2001b).

Rumble *et al.* (2001) placed four GPS collars and 44 VHF telemetry collars on cow elk. Each GPS collar collected more locations of elk in ten months, than was obtained from three technicians tracking ten times as many elk with VHF telemetry collars over 2.3 years. The average success in acquiring fixes was 88%. GPS has created new opportunities, animals can be track during nighttime or periods of bad weather, receive data by remote transfer, and collect considerable information about animals without disturbing them. Another study to identify the grazing patterns of hill sheep needed a system that is lightweight, robust, 24-hour availability, accurate positioning information and endurance of at least 7 days to ensure that the data is representative of the sheep's normal grazing pattern. The GPS with differential correction was chosen for this application, as this was the only existing tracking/navigation system that had the potential to meet the researchers requirements. They found that the GPS technique could be used as part of a system to allow the accurate determination of the home range of individual ewes (Rutter *et al.*, 1997).

1.6.2.4 GPS/GSM technology

According to Hulbert at an International Conference held in 2001, the greatest limitation to the universal use of GPS revolves around data retrieval. However, he said the most exciting development is the future integration of GPS with various radio technologies. The integration of GPS with satellite telephony or the GSM mobile telephone network may provide another solution to data retrieval. Quite sophisticated electronics are involved but do provide a solution to problems, retrieving data, especially on animals that can never be recaptured again (Hulbert, 2001).

Prior to the commencement of this study, no comprehensive study has been published that describes the use of GPS/GSM technology for the tracking of wildlife. However, at the end of this study, Jansson (2005) and Sundell *et al.* (2006) used the GPS/GSM technology for research on brown bears, emphasizing the advancement of this new technique for wildlife research.

1.6.2.4.1 Recent studies

According to Jansson (2005) who studied the habitat selection of five brown bears in central Sweden the GPS/GSM set-up functioned generally well, and the overall success for attempted position fixes were 76%. The precision of GPS and the frequency of positioning at regular intervals are far superior to the traditional methods of radio-tracking, which are limited in both precision and frequency, and are limited in most studies to daytime relocation. GPS/GSM allows for, or improves, studies of human ecology and behaviour at smaller and more detailed scales (Jansson, 2005). The advancement of the GPS-technique opens up new dimensions for wildlife research, especially for more in-depth fine scale studies of animal behaviour and habitat use. It allows for indirect observations studies of shy animals, in landscapes were they otherwise are rarely seen (Jansson, 2005).

Recent research on brown bears with GPS/GSM technology has shown that this method is reliable and accurate enough for the studying of animal behavior (Sundell *et al.*, 2006). The success rate for the GPS/GSM mobile phone tests in experiments without the bear was 99.1%. Advantages of this technology are that animals are easy to track directly in the field. The use of the mobile phone network for data transmission may lead to significant savings in large predator studies because the animals often move over long distances. Multiple animals can be tracked simultaneously from one place without the need for many researchers to follow the animals on foot or in motorized vehicles, as is necessary for traditional radio tracking (Sundell *et al.*, 2006). According to these researchers GPS mobile phone –based tracking will become the most-cost effective method for studying large animals in areas serviced by mobile phone networks.

1.7 Summary

This study was initiated, as it was believed that the combination of GPS and GSM would offer numerous advantages above VHF and satellite based techniques for the tracking of wildlife. As this is a new approach to animal tracking that has not been implemented successfully in the past, very little literature exists on previous studies. As this new concept offers totally new possibilities to end-users, the different possible market segments for such a system, as well as the requirements for the different market segments had to be studied before it would be possible to define the operational concept on which such a system could be based. It was therefore necessary to conduct a study to collect information from prospective end-users to develop the required insight into this market and the different ways in which a new generation of tracking technology could be deployed to optimally assist the management of wildlife.

Chapter 2

Analyzing market needs and developing a user requirement statement

Chapter two

2 Analyzing market needs and developing a user requirement statement

2.1 Introduction

Wildlife tracking is not a new concept: according to Hulbert (2001) field craft has grown into a biologist's science that has been enhanced by the advent of the most recent technologies. This chapter will focus on defining the needs of the market in order to develop a user requirement statement necessary for developing a new generation wildlife tracking system.

After starting the study on the industry needs it soon became clear that the wildlife tracking industry could be divided into a few categories of end-users, each with its own wildlife management objectives and therefore distinct needs for tracking animals.

- Private game farm owners
- Wildlife Researchers.
- National parks.
- Endangered wildlife organizations.

2.2 Developing a user requirement statement

2.2.1 Method

2.2.1.1 Participants

The needs of each one of these categories had to be understood to be able to come up with a final user requirement statement. A representative set of prospective end-users was identified from each of the above categories, and interviews were arranged to collect detailed information on the specific needs of these categories of end-users.

From discussions with different participants in this market it became evident that the local market leader was an existing commercial player, Africa Wildlife Tracking (AWT), specializing in the conventional tracking methods described earlier. It was decided to initiate discussions with AWT to consider the possibility of closer cooperation, not only in order to acquire more insight into market needs, but also to establish commercial cooperation through the joint development of a comprehensive wildlife tracking system. With more than 20 years of experience in the wildlife tracking industry and clients all over the world AWT was regarded as a very important source of information as they already knew exactly what their market needed. Each category of users was discussed with AWT, which also received much valuable information from their existing client base.

In this process interviews were conducted with the following end-users: Pilansberg Game reserve, Thaba Tholo Private reserve, Djuma Game reserve, the White lion breeding as well as the Leopard project near Hoedspruit, Phinda Game reserve in Kwa-Zulu Natal, the Kruger National Park, Amakhala Private Game reserve in the Eastern Cape, Shambala Private reserve, SanWild wildlife sanctuary and Save the Elephants organization situated in Kenya.

2.2.1.2 Questions during interviews

During the interviews we focused on the following aspects:

- What method of tracking is currently used if any?
- The reasons for tracking wildlife?
- What the client ultimately needs regarding tracking?
- How accurate must the locations be to suite their needs?
- What is the maximum size and weight that will be acceptable for their applications?
- How long must the batteries last?
- What does the term remote tracking mean?
- How frequently would they need a location of the animal being tracked?
- How would they like to receive and view the data?
- How long can they wait to receive the location data for the time the location was taken?

2.2.1.3 Feedback from the interviews

The following feedback was obtained from these entities:

2.2.1.3.1 Private game farm owners

Based on the interviews with AWT, private game farm owners rarely buy tracking equipment from them and if they buy equipment it is normally in conjunction with research projects on the farms.

- In the interviews with the farm owners the need of tracking for security and management purposes were identified. Animals like lion and elephant poses a threat to visitors and staff on the farms. A tracking system with the capability to notify staff when the animals are close to camps raised their interest.
- To be able to track expensive and dangerous animals like sable, lion, elephant and rhino to make sure they remain inside the reserve fences will be a big value add to game farm owners.
- To track animals enabling the rangers to easily find them when the owners want to do routine inspections would be another value add.

2.2.1.3.2 Wildlife researchers

- According to the interviews, researchers are the biggest buyers of tracking equipment by far. Researchers can extract much value from the ability to monitor animals remotely.
- To a researcher remote tracking means tracking without human intervention during the study period. Researchers need to track and monitor numerous animals all over the world at the same time.
- The frequency of locations to be reported can differ from once every 30 minutes to once every 24 hours to suite their needs.
- Researchers require easy access to the data. They need the data via e-mail or the Internet. Although it must be easy to access, security is quite a big issue to ensure that no one else can access their data.
- Most researchers only needs the raw location data and will use existing analytical packages like arc-view on which to view and analyze the data.
- A simple interface to view and replay the data on a map would be a good value-add to be used where sponsors are involved. Sponsors would be given access to the interface to track the animal they are sponsoring.

- Position accuracy is a definite requirement, ten-meter accuracy would satisfy the needs of all researchers.
- Timing accuracy is a requirement for studies where locations need to be taken on different animals at the same time (within a minute) to determine their location with respect to one another.
- The time before receiving the location data from the collar needs to be as short as possible where management and security is part of the projects. Being notified of an animal breaking out or nearing a camp should be reported as soon as possible (within minutes). For most pure research applications getting the data within the next few days or even months is sufficient. For users using the data for academic studies getting the data as soon as possible are important as they need the data to complete their research studies within a specific time frame.
- The device should last at least one year without any human intervention but preferably two years or more.
- The device must be small enough to track smaller animals like wild dog and even bigger bird species.
- The tracking system must be able to interface with cell phones to make it a truly remote tracking solution enabling researchers to track animals while in the field searching for the animals to do observations.

2.2.1.3.3 National Parks

- The need for tracking in national parks is also linked to the research done in these parks. After interviewing a number of sources from the Kruger National Park regarding tracking without much success, we were referred to dr. Gus Mills, a researcher in the park and head of the carnivore conservation group of the Endangered Wildlife Trust (EWT) doing research and protecting especially wild dogs (www.ewt.org.za). He confirmed that our list of requirements for research was valid and that he would definitely consider using a system meeting the needs as described above.

2.2.1.3.4 Endangered wildlife organizations

- The main aim of organizations like EWT is to protect endangered species (www.ewt.org.za) A big part of doing this work is funding research on the endangered species that led back to the requirements for researchers as mentioned above.
- Other needs include the monitoring of the animals for security purposes.
- Monitoring of rehabilitated animals to see how they cope back in the wild.
- Geo-fencing will be very helpful as it is important to these organizations to know when the animals break out of the protected areas and are in danger of being killed by neighboring farmers.

2.3 A user requirement statement

The user requirement statement was compiled by combining the requirements of wildlife researchers with the few additional requirements for wildlife management as stated above. The main user requirement was divided into the following subsystems:

- Positioning technologies,
- data transfer and
- data distribution.

Based on the quantified feedback collected from prospective end-users, the following requirements were determined:

2.3.1 Positioning technologies

- A position accuracy of 20 meters
- The positioning module must be as small and lightweight as possible to ensure a wide range of applications on different mammals and large birds.
- Power consumption of positioning module: – At least 3000 readings per D-Cell battery. (which translates to <4.3mAh per location).
- To be operated from a single high capacity cell it had to use a power supply of 3.6V.
- The power supply will contribute to the size and weight of the tracking unit and therefore the module must be as power efficient as possible
- Price of positioning module: less than R3000 per module.
- No human intervention necessary in the positioning process.

2.3.2 Data transfer

- The size of the module must be as small and lightweight as possible to ensure a wide range of applications on different mammals and large birds.
- Power consumption of data transfer module: – At least 3000 readings per D-Cell battery. (i.e. <4.3mAh per location).
- Price: less than R2500 per module.
- Capable of downloading at least 24 locations, each requiring 64 data bytes, (i.e. 1535 bytes of data) per day.
- To be operated from a single high capacity cell it had to use a power supply of 3.6V.
- A global tracking system, i.e. tracking anywhere in the world with monitoring from a central point.
- A possibility to schedule the device to report the locations from once every 30 minutes to once every 24 hours, within an accuracy of one minute.

2.3.3 Data distribution system

- A system providing geo fencing, i.e. it must support the implementation of no-go zones and provide notification when a violation occurs.
- A system supporting tracking from a Cell-phone when in the field.
- An easy-to-use interface to download and view the data on a map worldwide.
- An option to export data into csv (comma separated values), Arcview and other commonly used data file formats.

2.4 Summary

After the compilation of a user requirement statement according to the interviews with the different entities, an interview with AWT confirmed that the requirements as described above were valid for the wildlife tracking market. These requirements must be met by a new generation wildlife tracking system.

Chapter 3

Technology survey

Chapter three

3 Technology survey

3.1 Introduction

Using the user requirement as obtained in chapter two as a reference a study was conducted to find possible technologies to use in the design of a system meeting the needs mentioned. The positioning and data transfer and distribution technologies were evaluated against the user requirement statement in Chapter 2 (2.3).

3.2 Positioning technologies

3.2.1 Radio telemetry

The disqualifying factor for this option is the fact that a human operator is needed to do the tracking, violating the "No human intervention criteria". It was therefore not deemed necessary to evaluate this option in terms of the other criteria.

3.2.2 Cellular Location based services

According to Kolodziej (2006) tracking using only a cell phone is getting more and more popular. A drawback to this technology is that it is not very accurate. The mobile network calculates the position of cell phones on the network but the accuracy is limited to 50-300 meters. Cell tower triangulation is not sufficiently accurate – mobile networks can calculate a position, but the accuracy is limited to 50-300 meters.

When a cell phone is turned on and connected to the cellular network, most wireless carriers can locate your device on their networks according to Milroy (2002). Location is determined through Cell Site ID and a tower to which you're actively connected. Current levels of accuracy are however between 1 mile and 5 miles (Milroy, 2002) making this option unsuitable.

One of the most used and well known Cellular Location based services in South Africa is the Vodacom Look4me service. This cellular Location based service currently does not use triangulation and it is therefore not very accurate. Instead, each base station divides the area it covers into three or four quadrants. The software checks which quadrant the user is in and positions them in the middle of that quadrant, using the distance from the middle to the edge of the quadrant as the approximate accuracy of the location given.

According to Anon (2004a) the approximate location will be accurate to around 50m, when the cellular density is high. This level of accuracy will only be available in an area like Sandton, Johannesburg, which is not relevant for wildlife tracking applications. In typical rural areas, as would be applicable to most wildlife tracking applications, base stations cover several kilometers. A location query in the Karoo would probably position the user within an area of 5km, which is not sufficient for research purposes (Anon, 2004a).

The Cellular location based service is not accurate enough – 100m to a couple of kilometers and positioning are only possible when the tracked object is in cellular coverage disqualifying this technology. Another big drawback to this technology is that it is not universal. Every network offers their own solutions making it difficult to use globally.

3.2.3 ARGOS satellite triangulation.

ARGOS allows the location of any platform equipped with a suitable transmitter, anywhere in the world, to within 150 to 1000 meters (using Doppler effect) (Anon, 2005a). For some applications the ARGOS satellite system would be sufficient to locate an object fit with an ARGOS transmitter. The accuracy of 150m – 1000m did not meet our criteria.

3.2.4 Global Positioning System (GPS)

The global positioning system is widely used in all sorts of positioning products as it was designed to determine the exact position of an object anywhere on earth. The concept and technology is discussed below (Bogan, 1998).

3.2.4.1 Concept

Firstly the satellite's position is detemined relative to the earth and then the location on earth is located relative to the satellite. The position on earth can now be determined by the vector sum of the other two measurements. All measurements are done to such a precision that the location on the earth is known within 15 m.

3.2.4.2 Methods

The satellite's position is determined by high resolution radar observations, then precision orbital parameters are determined to prepare accurate ephemerii. The following small perturbations must be included in the preparation of the ephemerii.

- Non-spherical shape of the Earth (causes precession of the orbit)
- Tidal attraction
- Solar Radiation and Winds
- Air Drag
- Relativistic Effects
- Solar and Earth Magnetic Fields

The distance from the satellite is determined by the time it takes for a radio wave to reach the site from the satellite.

$$\text{Distance} = (\text{speed of light}) \times (\text{time of flight})$$

Although this is very simple, there are a few difficulties:

- The clock of the receiver used on earth is not exactly synchronized with the satellite clock so the time of flight will be imprecise.
- The satellite and receiver are in different velocity reference frames and gravitational regimes so there are relativistic differences (both special and general)
- The speed of light is 300,000 km/s in a vaccum. However, while travelling through the Earth Ionosphere and Troposphere, the radio waves travel at slightly slower speeds affecting the time measured.

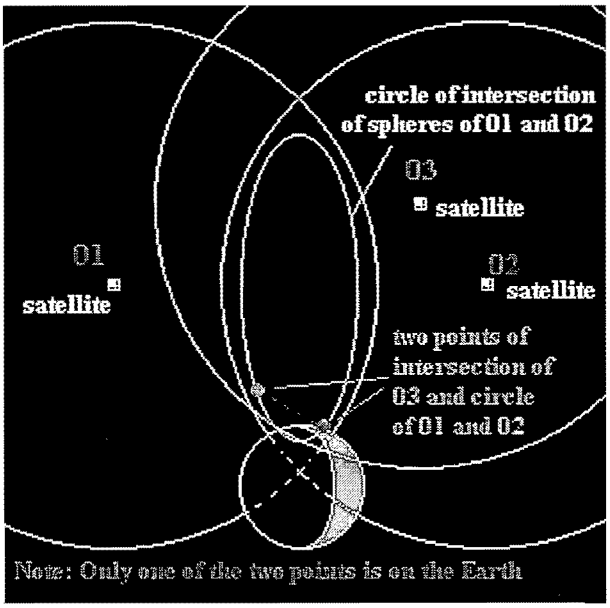
- Radio signals traveling through the atmosphere travel differents paths depending on the location of the receiver, this will affect the time measuments as well.

The location is a vector and must also include direction. In order to do this, distances from several satellites are required. This is called triangulation. We wish to find our latitude, longitude and height above the center of the Earth. These are three different numbers and would require distances to three different satellites.

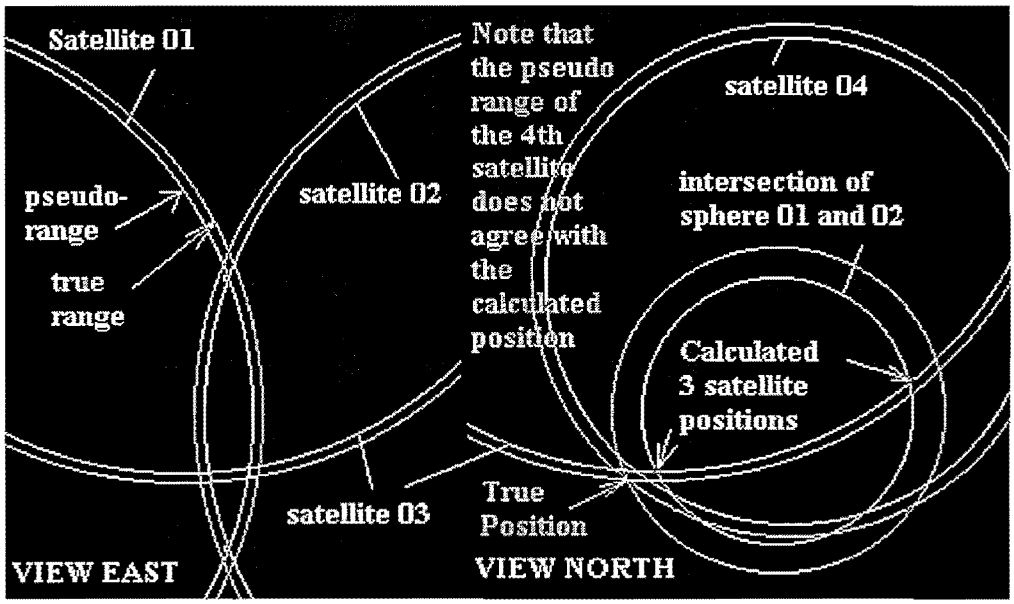
3.2.4.2.1 Elaboration of the method (Bogan, 1998)

How does the GPS know the direction and time of flight since the satellite and the GPS are not synchonized?

- How does the GPS know the location of the satellite.
    - Satellite signal sends time
    - Satellite signal sends orbit parameters
- Direction: Three satellites must be used to uniquely determine the GPS's location relative to the satellite. The technique is based on the intersection of three spheres representing the signals that were received at the same time from three different satellites. Two points are uniquely determined by these intersections.



- **Time Synchronization:** The satellites have highly accurate atomic clocks but the GPS has a much less accurate and less expensive clock. As a result the GPS will not have exactly the correct time that it took for the radio waves to travel from the satellites. As a result the wrong position will be determined. A fourth satellite signal is needed to correct the time error.



- Calculations are performed by the GPS receiver using data sent from the satellites .

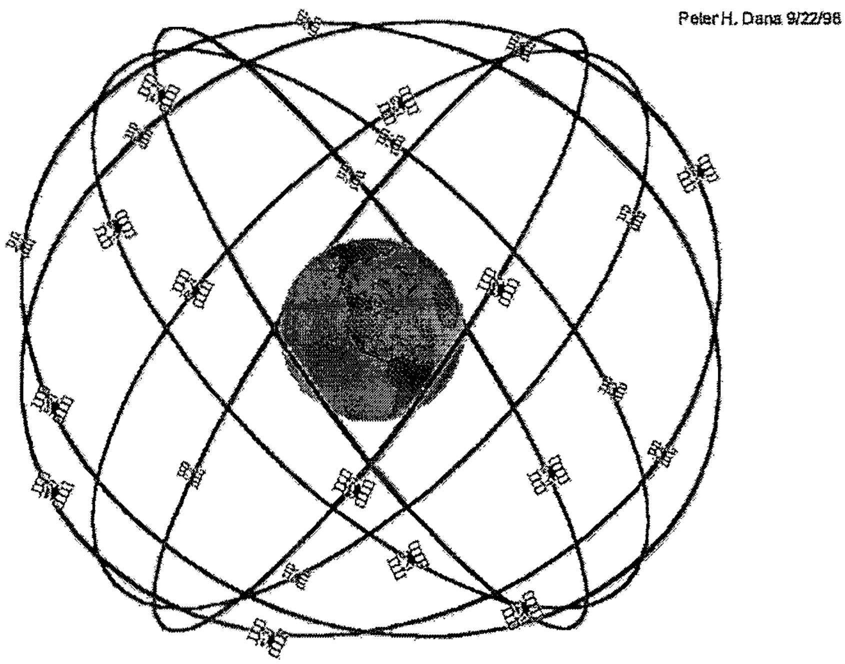
3.2.4.3 Physical Components (Bogan, 1998)

3.2.4.3.1 The Satellites

GPS satellites have four onboard atomic clocks with accuracies of 1 part in 10^{14} per day. Lifetime of each is about 10 years. Mass = 1500 to 2000 kg.

3.2.4.3.2 The Orbit

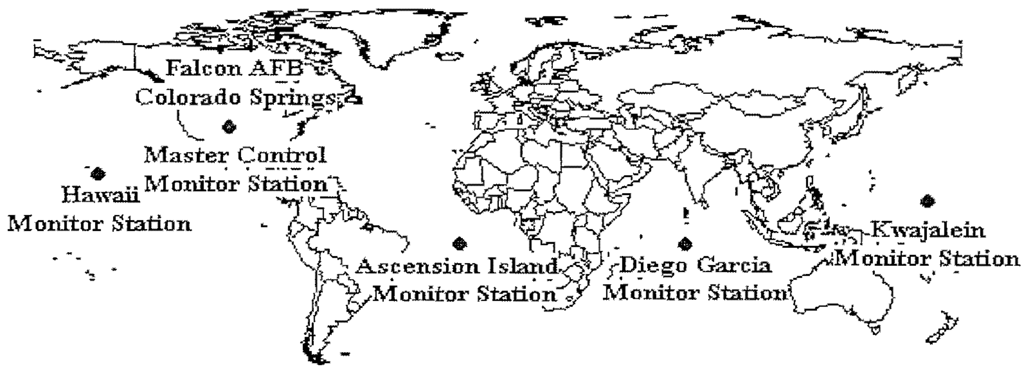
Twelve hour orbital periods put the satellites in orbits with 26,600 km radii, which makes them more stable than low Earth orbits. Satellites repeat the same track and configuration over any point approximately every 24 hours. (Their orbital period is 11 hr 58 minutes so they shift arrival time by four minutes every 24 hours) At least



GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

five to eight satellites are visible anywhere on the Earth at any time (usually more).

3.2.4.3.3 Monitor and Control Stations



Global Positioning System (GPS) Master Control and Monitor Station Network

The US Department of Defense constructed and maintains the system of GPS satellites. Costs of $12 billion with replacement satellites committed to 2006. The monitoring stations continually monitor satellite positions and provide updated times and ephemeris for the satellites to keep them in synchronism with standards of time and position on the Earth. The Master Station in Colorado provides precise timing and calculation of orbit parameters.

3.2.4.4 Typical GPS receiver module

A typical commercially available GPS receiver module will have the following basic specifications:

- Accuracy

  Horizontal: <5 meters (50% of the time), <8 meters (90%)

  Altitude: <10 meters (50%), <16 meters (90%)

  Velocity: 0.06 m/sec

- Dimensions: 26 mm W x 26 mm L x 6 mm H
- Weight: 6.5 grams including shield
- Prime Power: +3.0 VDC to 3.6 VDC (3.3 V typ.)
- Power Consumption: Less than 90 mW (27 mA) @ 3.3 V

3.2.5 Conclusion

From the above analysis it is clear that GPS is the only tried and tested positioning technology meeting our requirements in Chapter 2 (2.3). As mentioned above the second problem to solve was around remote wireless data transfer technologies.

3.3 Remote wireless data transfer

Wireless communication and data transmission techniques are very popular. It can be divided into two categories, short range and long range. For short range there are infrared data association (IrDA), bluetooth, and IEEE 802.11× technologies, while radio and satellite technologies fall into the long-range remote wireless communication category (Tseng *et al.*, 2006). According to the market requirements (2.3.2), the long-range options for data transfer had to be evaluated.

3.3.1 Wireless Radio communication

The option to download data from the device on the animal to a handheld or stationary receiver was considered. To make this system truly remote, with no human intervention, the complete study area had to be covered with stationary receivers. Due to the fact that the device had to be very small, a problem occurred for choosing the right frequency for data transfer. There is no space for a long antenna, so we had to look at frequencies of 600MHz or higher to be able to design efficient antennas for the space available. To get a range for this kind of frequencies the power output must be high which will use too much power. To solve this more than one stationary receiver could be used. Another problem was to get a globally legal license free band to use. This will require the design of a small cellular network, similar to the existing GSM system. As the costs involved are beyond the level of affordability of this market, this is not a viable option.

3.3.2 GSM (Global system for mobile communications)

According to the GSM Association (2006) the Global System for Mobile communication (GSM) is an open, digital cellular technology used for transmitting mobile data services and voice. A big difference between GSM and first generation wireless systems is that GSM uses digital instead of analog technology and time division multiple access transmission methods.

GSM is a circuit-switched system dividing each 200kHz channel into eight time slots (25kHz each). GSM operates in 4 bands over the world; 900MHz and 1.8GHz or 1.9GHz and 850MHz. Roaming agreements between the GSM networks will enable you to access the same services when traveling abroad as at home. GSM satellite roaming also extends coverage to areas where terrestrial coverage is not available. Data transfer speeds of up to 9.6 kbit/s are supported, allowing the transmission of basic data services such as SMS (Short Message Service) (GSM Association, 2006). GSM offers a few services of which the first is voice. We are however more interested in the data transfer services:

Two circuit-switched data protocols are defined in the GSM standard

- Circuit Switched Data (CSD)
- High-Speed Circuit-Switched Data (HSCSD)

These connections are normally charged on a per-second basis, regardless of the amount of data sent. Circuit-switched connections provide a constant, guaranteed quality of service, which is useful for real-time applications. Power consumption might be a issue here because of the fact that you have a real-time connection (Anon, 2006).

3.3.2.1 GPRS

The General Packet Radio Service (GPRS) is a packet-switched data transmission protocol (Anon, 2006). Data is transferred using GPRS by sending packets to the mobile phone mast (BTS) on channels not being used by circuit-switched voice calls or data connections. The advantage to this is that multiple GPRS users can share a single channel because each of them uses it only for occasional short bursts. This type of connection is typically billed per kilobyte of data sent opposed to per second. This is usually the cheaper alternative for applications that only need to send data when needed, like instant messaging (Anon, 2006).

3.3.2.2 Short Message Service (SMS)

SMS provide a means of transmitting messages between mobile devices and Short Message Service Centers via the Short Message Service (SMS) (Anon, 2006). Only 160 bytes can be sent in one SMS. Due to the fact that this messages is not send over an already established dedicated link like in the case of a voice call we found that the messages can get delayed.

3.3.2.3 Advantages and sustainability

The following statistics showed that GSM was here to stay and that it was a technology worth investing in (GSM Association, 2006).

- GSM is the fastest growing communications technology of all time.
- The billionth GSM user was connected in the first quarter of 2004 - just a dozen years after the commercial launch of the first GSM networks.
- The second billionth GSM user was connected in second quarter of 2006 - just two and a half years after the first billion.
- Today, GSM accounts for 82% of the global mobile market.
- 29% of the global population use GSM technology.
- The GSM Association currently has operator members in more than 210 countries and territories.
- GSM has been dubbed the "Wireless Revolution" and it doesn't take much to realize why (Huynh, 2004).
- GSM provides a secure and confidential method of communication (Huynh, 2004).

The module we were looking at had the following specifications:

- Dimensions: 58.4mm x 32.2mm x 3.9mm
- Prime Power: 3.3V- 4.5V

At his stage GSM seemed to be a very feasible technology to consider. Using the commercial Cellular network would reduce the installation cost and provide an easy and readily available network solution. (Tseng *et al.*, 2006) The low power transmission requirements of GSM will definitely be a workable choice. GSM also provides data encryption for better data security in this application. (Tseng *et al.*, 2006). GSM met all our criteria but the downside to this technology is that although the GSM network is rapidly expanding there are still places with no coverage. If GSM was to be used this obstacle had to be overcome.

3.3.3 Satellite communication

A newer method of tracking is satellite tracking. Satellite tracking can be divided into two kinds. The first kind uses low orbiting satellites to receive a signal transmitted by a transmitter collared to the animal. The ARGOS satellite system is based on this concept (Service Argos, Inc., 2005).

The Argos receiving equipment are installed on board the National Oceanic and Atmospheric Administration (NOAA) Polar Orbiting Environmental Satellites (POES). These satellites receive the signals transmitted by the ARGOS transmitters and retransmit them to the ground. The received data is also stored and dumped to three main ground stations when the satellite passes by. The three ground stations are: Wallops Island, Virginia, USA; Fairbanks, Alaska, USA; Lannion, France. A minimum of two satellites is operational at a time. The satellite orbital planes rotate about the polar axis. One revolution around the earth takes approximately 102 minutes. Because these satellites are in a polar orbit, the latitude position of the transmitter affects the number of daily passes over the transmitter. The larger the latitude the more passes per day. The satellites pass the poles 14 times per day (28 for two satellites) and the equator six to seven times per day in total. This fact limits the positioning frequency per day. The times of the location cannot be specified either, as the transmitter gets tracked when the satellite passes by (Service Argos, Inc., 2005).

The second kind of satellite tracking is where the GPS is used to get a location and the satellite is used to relay the data from the transmitter on the animal to some ground station in contact with the user of the system. Inmarsat D+ system works on this principle. The geo-stationary satellites make 24-hour communication possible. This system uses the (spot-beam) Inmarsat Phase three satellites which enables smaller, lower power transceivers to be put on the animals (Meldrum *et al.*, 2001).

Mobile satellite systems (MSS) may be classified according to orbit altitude as follows (Meldrum *et al.*, 2001)

- GEO – geo-stationary earth orbit, approx altitude: 35 000 km
- MEO - mid-altitude earth orbit, approx altitude: 10 000 km
- LEO - low earth orbit, approx altitude: <1 000 km

LEOs can be further sub-divided into Big LEO and Little LEO categories. Big LEOs will offer voice, fax, telex, paging and data capability, whereas little LEOs will offer data capability only, either on a real-time direct readout ('bent pipe') basis, or as a store-and-forward service. Since the satellite footprint decreases in size, as the orbit gets lower, LEO and MEO systems require larger constellations than GEO satellites in order to achieve global coverage and avoid data delays. Less energy is, however, generally required for LEO and MEO satellite communication because of the shorter average distance between transmitter and satellite. Some systems implement several high-gain antennas to generate spot beams and so reduce the requirement of the mobile to have a complex antenna and/or high output power. A key feature of several MSS currently under development will be their inter-operability with existing public switched telephone and cellular networks, using a dual-mode handset, for example (Meldrum *et al.*, 2001).

The biggest factor of concern about satellite communications is that the satellite communication OEM modules did not meet the size criteria and that it is not easily available. As one of the aims of the satellite technology development is to interface with the GSM networks.

3.3.4 Conclusion

From the above analysis it is clear that GSM is the only system for data transfer, meeting our requirements in Chapter 2 (2.3.2).

3.4 Data distribution

A control server would act as a gateway between the end-user and the animal. The data from the animals would be received, interpreted, stored in a database and made available over the Internet for users to view all over the world. For users that spend most of their time in field, the server will forward the incoming data to user's cell phone. The control server could also act as a manager, monitoring the movements of animals, comparing them to boundaries (geo-fencing) and rules set by the client. Data would be distributed to the users using GSM, E-mail and the Internet. Software will be developed to meet the user requirement. A combination of the above mentioned technologies would meet the user requirement for data distribution in Chapter 2 (2.3.3).

Chapter 4

System concept design

Chapter four

4 System concept design

4.1 Definition of the system

Against the background as described in the previous chapter, Yrless International (Pty) Ltd. has developed a definition of a product that will solve the majority of wildlife tracking and management problems experienced by the target market utilizing the available technologies as described in chapter 3.

The system will consist of two main parts:
The first part will be the location device to be fitted to the animal and how the data is distributed to a single point. The second part will be the intelligence to decode and interpret the data received at the single point and to distribute is to the user/users.

4.1.1 Location device on the animal

The main requirements for this device extracted from the main user requirement are stated in Chapter 2 (2.3).

The first problem to solve was getting an accurate location of the device. As stated in the technology survey, GPS was the most suitable technology to use. The following is the specifications for the GPS module as retrieved from the module datasheet and verified in the field.

4.1.1.1 GPS module

4.1.1.1.1 Accuracy

Variance in the horizontal plane:

- Horizontal: <5 meters (50%), <8 meters (90%)

Variance in the vertical plane:

- Altitude: <10 meters (50%), <16 meters (90%)

Variance in the velocity:

- Velocity: 0.06 m/sec

4.1.1.2 Acquisition

The time to get a GPS location fix differs for the different states of the GPS module. When the module is permanently on but looses the GPS signal due to an obstruction, the time it takes to get a new location after the signal is restored is less than two seconds 90% of the time.

- Reacquisition: <2 sec. (90%)

If a module was off or obstructed for less than 1 hour and comes back on again it is called a hot start.

- Hot Start: <10 sec (50%), <13 sec (90%)

If a module was off or obstructed for more than one hour and less than 24 hours and comes back on again it is called a warm start.

- Warm Start: <38 sec (50%), <42 sec (90%)

If a module was off or obstructed for more than 24 hours and comes back on again it is called a cold start.

- Cold Start: <50 sec (50%), <84 sec (90%)

According to the GPS module's specifications it could report an accurate location from a cold start (no initialization) within 80 seconds, warm start (last position, time and almanac are saved by backup power) within 40 seconds and hot start (ephemeris also saved) within 15 seconds (Anon, 2004b).

The GPS module also reports the exact time. This time could be used for the required scheduling. The problem with this would be that the GPS module had to be active all the time to be able to read the time from it. This would draw to much power to meet a battery lifespan of two years, as with operation based on this way the one D-cell battery would only last about 13 days powering the GPS module. To solve this problem a low power, real time clock (RTC) was used to do the timing. On power up the clock started counting and two alarms could be set to go off at certain times from then. At these times the RTC would wake up the processor switching on the GPS module until it got a location and switch it back off. Using this approach one D-cell battery would last approximately 1233 days if the device took 12 location readings per day and it took 60 seconds to get a valid location.

Non-volatile memory was added to store the locations taken on the specified time intervals. The memory could store up to 4000 locations with the option to extend the memory to store up to 32000 locations. At this stage we already had a GPS data logger product able to take and store about 3000 GPS locations on specified times using one D-cell battery. This product could be sold to researchers willing to wait until the device was removed from the animal to receive their data.

Although we had a product at this stage it did not meet the market needs. The second challenge was to get the data to the users automatically as soon as a new location became available.

4.1.1.3 GSM module

As stated in the technology survey (Chapter 3), GSM was the only viable technology to use. The GSM module enabled us to send the location data via SMS to the user. Like with the GPS module power consumption was a big problem. One D-cell battery would only last about 14 days if the module were active all the time. The advantage to this would be that the user would actually be able to request a location from the device at any time using GSM. This however was impossible to do with the power we had available. It was decided to also only switch on the module on the specified times just after the GPS module to send the data and switch it off again immediately after the transmission was concluded. Time had to be allowed for the module to register on the cellular network and receive new schedules or settings from the user. The GSM network keeps SMS messages sent to the device while it was off it takes about one minute, when the device comes on to receive the messages.. The GSM module had to be switched on, register on the GSM network, wait for messages from the user and send any new stored data via SMS. This way about 3000 GPS locations could be sent to the user using one D-cell battery. For cases where the users could wait a while to receive the data, three locations could be sent in one SMS making it more cost and power effective.

4.1.2 Interpreting the data received

At this stage we had a small, low power GPS/GSM tracking device able to report GPS locations on specified times sending it to the user just after it was stored. The user would receive the data on his/her cell phone as an SMS. Although this is already useful it still did not meet the user requirement. The data needs to be easily accessible from anywhere by more than one user and needs to be plotted on a map. The data also needs to be exportable to arc-view or excel format. As part of the business strategy the decision was made to make all the devices report to a central point and for data to be distributed from there. This would give us full control over all the devices in the field eliminating human error by users. The central point would be a control and web server. The control server would act as a gateway between the end user and the animal. The data from the animal would be received, interpreted, stored in a database and made available over the Internet for users to view from anywhere in the world. Users would be able to change the schedules and settings of the tracking device using a web-based interface. For users that spend most of their time in the field, the control server will forward the incoming data to the user's cell phone via SMS. The control server could also act as a manager, monitoring the movements of the animal and comparing them to boundaries (geo fencing) and rules set by the client. When a violation occurs the user will be alerted via SMS. Using the control server to decompress locations would enable us to compress the GPS locations and fit eight location readings into one SMS instead of three. Hosting the control server would enable YRless to give excellent customer service, as we would have all the data readily available. Faultfinding would be much easier having data from all customer devices on the server.

For the users to view their data user software would be developed for users to install on their PC's. The software enables users to:

- Download data from the YRless International database through the Internet.
- View the data in a user-friendly environment, including a mapping interface for the location data points to be displayed on a detailed map.
- Provide an interface to change device settings like switching the beacon transmitter on/off or change reading schedules.

- Configure the automatic manager at the control center by specifying zones where the animal may or may not be.

Due to the fact that the animal tracking industry is a very high risk market with costs of up to R30 000 just to fit a tracking device, a backup tracking method was needed to enable users to at least find the animals again if the GPS/GSM unit should fail or if the animal moves out of cellular coverage. The conventional RF beacon transmitter was added for this purpose.

4.2 Summary

A system has been defined to meet the market needs as described in chapter two using the technologies as described in chapter three. Two main parts of the system was addressed. Firstly the device on the animal reporting its exact location to a central point and secondly the intelligence to decode and interpret the data received at the single point and to distribute is to the user/users. A lot of challenges regarding power consumption were discussed and solved moving ever closer to a product meeting the user requirement.

Chapter 5

Deployment and Field Testing of the Wildlife Tracking Concept

Chapter five

5 Deployment and Field Testing of the Wildlife Tracking Concept

5.1 Introduction

Chapter five describes how the prototype system based on the design described in the previous chapter was deployed in the field to enable the practical assessment of how this system would perform in typical application environments. It furthermore describes how these results were used to update the existing knowledge base regarding the needs of end-users and the way in which the system was employed in the field. Based on this practical feedback, the key research question could be answered: Will a new generation wildlife tracking system based on a combination of GPS/GSM technology offer numerous advantages above existing technologies?

5.2 A basic description of the wildlife tracking concept

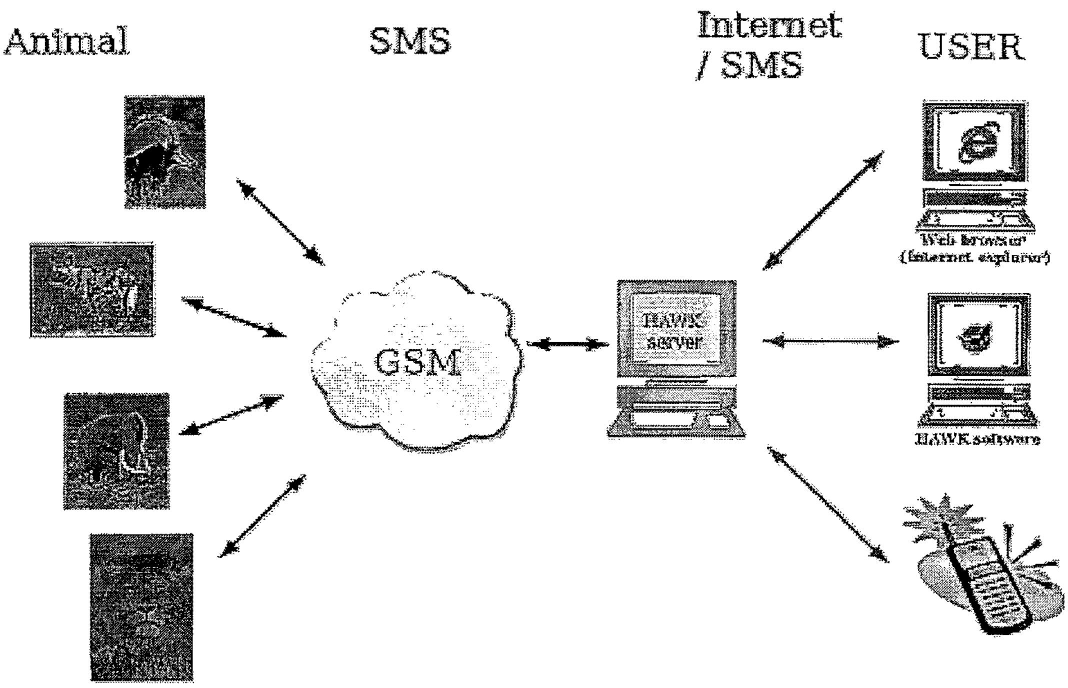


Figure 1: System diagram

The wildlife-tracking concept was practically tested based on the HAWK105 system developed by Yrless International (Pty) Ltd. HAWK105 is a satellite based monitoring system designed to provide operators and customers with clear visibility of the location of tagged animals through scheduled reporting. It uses the Global Positioning System (GPS) to accurately pinpoint current location, velocity and heading on user-specified times. This data is transmitted via a GSM network (SMS) and made available through the Internet on a 3D map or via SMS's to users worldwide.

5.2.1 Main Features

1. Automatic GPS location reports, stored and sent at user defined times.
2. Set times or intervals for the device to report on request from the user.
3. All schedules are remotely programmable schedules via web interface.
4. Dual band GSM communication.

5.2.2 Tracking interface

5.2.2.1 Data Presentation

- Positions viewed on Google Earth 3D mapping software using the HAWK software (Figure 2).
- Data is stored on the user's personal computer for analysis.
- All data are backed up on the main server.
- The HAWK software provides: Tabular, Map based (Google Earth), file export and historical data replay capabilities.

Figure 2: Screenshot of the HAWK software

5.2.3 Device configuration

- Over the air configurable via secure web interface.
- Enables remote changing of reporting schedules, settings.

5.3 Method for deployment and field testing of the tracking system

The HAWK 105 tracking system was deployed in the field to enable the practical assessment of how this system would perform in typical application environments. Three prototype-tracking devices were supplied to AWT to give to some of their clients for testing. AWT collared the devices and supplied one collar for a lion in Pilanesberg National Park, the other for a sable in the Kruger National Park and the third for an elephant in Kenya.

5.4 Results

After the collars were deployed both the sable and the lion moved in and out of cellular coverage on a regular basis. The longest continuous time out of coverage was 30 days. The sable collar functioned for 440 days before it was removed.

The lion collar functioned well for three months and then suddenly it could not get a GPS fix any more. It still sent SMS messages but with no valid GPS fixes. After the collar was removed and sent back to us we opened it up and saw that the wire running in the collar connecting the device with the GPS antenna broke. The elephant collar in Kenya is still functional after 2.9 years in the field. The following table (Table 1) contains statistics about the collars.

Table 1: Statistics from the collars

Collar statistics	**Sable**	**Lion**	**Elephant (Kenya)**
Lifetime (days)	440 days	161 days	1003+ days
Number of sms'es:	1838	859	7091
Number of scheduled readings	3813	2514	36029
Number of valid GPS fixes:	3213	1212	34690
Number of 3D GPS fixes:	3032	1034	33507
Number of invalid GPS fixes:	583	1290	1327
Number of setting changes by users:	17	12	136
Number of locations in cellular coverage:	1795	206	5499
Number of locations outside cellular coverage	2018	1009	27144

Due to the confidentiality of the data of the Sable and the Elephant the following map will show only the positions collected for the lion in Pilanesberg. The purple points show GPS locations outside cellular coverage.

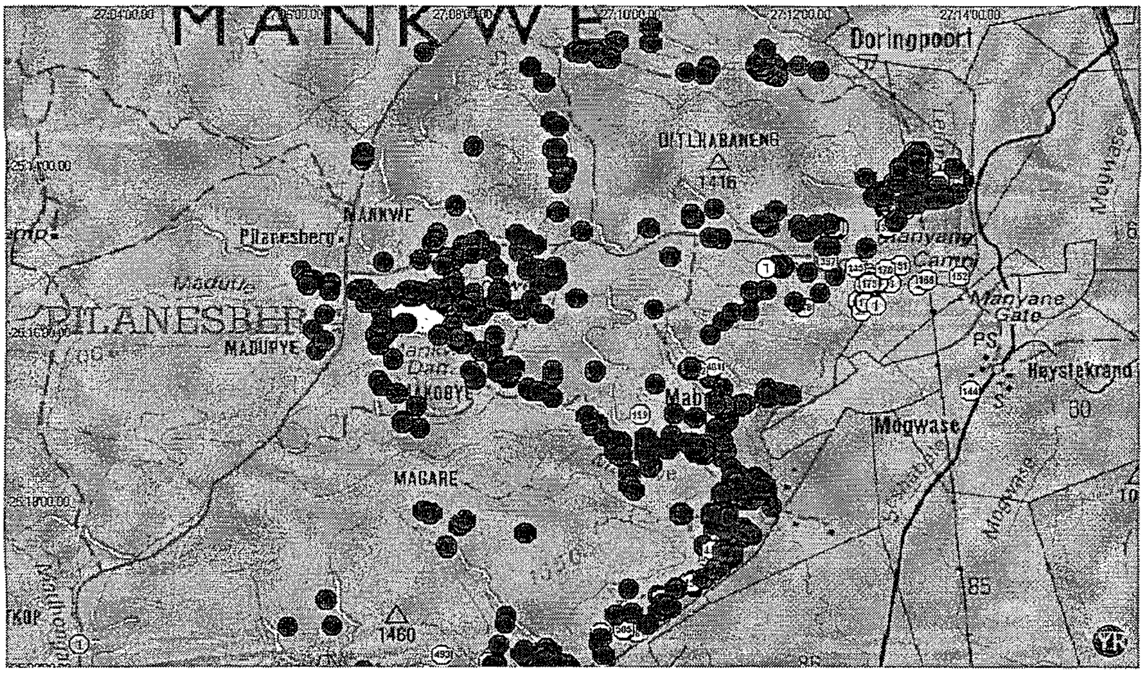


Figure 3: Data points from the lion in Pilanesberg

5.4.1 User software

The user software performed as specified giving the users immediate secure access to their data via the Internet. One of the users did request a function to replay the data point by point. This function was added to the user-software enabling users to replay the GPS locations and times one by one. With the international collar it became necessary to add a function to set the time zone that the collar was in to show the location times in the user's local time.

5.5 Conclusion

The GPS/GSM tracking system meets the user requirement in Chapter 2 (2.3). The lack of complete cellular coverage in the study areas caused the collars to act as data loggers while not in coverage. It was not a problem in this case due the nature of the projects but the lack of real time data could cause problems in other applications. The fact that the batteries lasted for 3813 readings in the sable and 36029 readings in the elephant collar confirms the low power requirements of the device. The GPS/GSM technology in the lion collar still meet the user requirement, even though it stopped functioning after 161 days, due to a collaring failure. The difference between the performances of the 2 identical GPS/GSM devices is due to the different scheduling, packaging and animal behavior.

5.6 Changes in system specifications

There were no changes in the system as the devices performed according to the specifications.

Chapter 6

Evaluation of market response to the product

Chapter six

6 Evaluation of market response to the product

6.1 Introduction

The tracking system was evaluated by analysing the data received from devices already deployed and looking back on lessons learnt to date. Futhermore the success of the system was stated by evaluating the main features and requirements of the system using feedback from the market as published in the media.

6.2 Approach used to perform evaluation

Evaluating the device's functionality was easy due to the fact that all the data from the collars is channeled through our servers and is captured on our database. Logs were kept on every user logging in. In this way we could see exactly how the devices were performing in the field and how the users were using the product. More than 1.5 million GPS coordinates reported by our devices in the field and about 230 users on the system prove that the system is being used very intensively.

Up to the present over 300 devices were deployed in the field. A few failures were experienced, mostly during the early phase of deployment, due to a number of reasons. Four of the devices malfunctioned without having external damage. In all four cases the problem was the batteries not being able to deliver enough peak current to the device. This caused a voltage ripple that did not meet the specifications of the cell phone causing the device to reset. Implementing a low pass filter, to filter out the ripple solved the problem. Physical damage to the device or collar was the biggest reason for devices that stopped functioning. A few units got wet inside due to too little potting material around it because of the importance to keep the size and weight down to a minimum. Like mentioned previously the packaging (collaring) was outsourced to Africa Wildlife Tracking, who acted as reseller of our products, and these problems were therefore not the direct responsibility of YRless International (Pty) Ltd.

The feedback received from devices in the field and clients is constantly used to improve the product and supporting services. The most important measure of success was the overall response from the market. Up to 300 devices were sold up to the end of this study, this answers the question if the end-users would buy the product and be satisfied. Average sales per year are still increasing and each device in the field generates a monthly income which, combined with the long battery life, ensures that a sustained monthly income is generated.

To provide proof that many users were satisfied, a few articles from our clients that were published in the media are included in the Appendix.

6.3 Evaluation of the main system requirements by the end-users

- *Power consumption of the positioning and data transfer module: – At least 3000 readings per D-Cell battery. (i.e. <4.3mAh per location).*

  Currently devices lasts 2 years and more for 5 readings per day on 1 D-cell battery (3650 readings).

- *To be operated from a single high capacity cell it had to use a power supply of 3.6V.*

  All components is operating from a 3.6V power supply, meeting the user requirement

- *The positioning and data transfer module must be as small and lightweight as possible to ensure a wide range of applications on different mammals and large birds.*

  The system is being used on vultures proving that the size and weight requirement was satisfied. The following remark from one of our clients provides evidence to this effect: "Tracking vultures to determine their movements is part of the De Wildt Vulture Unit's commitment to the saving of this majestic species. Some vultures have been fitted with cellular tracking devices and this has also proven to be a valuable method of tracking the birds in real time". (www.dewildt.org.za)

- *A position accuracy of 20 meters*
- The position accuracy proves to be as accurate as specified in our GPS module specifications. Placing our devices on different points proved this by verifying the

GPS coordinates against very accurate satellite scans. The accuracy proved to be better than 10m 99% of the time on 100 different locations. *A possibility to schedule the device to report the locations from once every 30 minutes to once every 24 hours, within an accuracy of one minute.*

The first devices we sold had a drift of about one minute per week for hourly readings. This was rectified and current collars reports on specified times with an accuracy of +/- one minute. This fact is proved by all the GPS locations received, as every point is GPS time stamped with an accuracy of one second. Clients are also satisfied with the scheduling which make the product very versatile as stated in the following remark: "Not all users chose to receive data every six hours. Scientists, conservationists and game rangers vary the frequency of the updates depending on what animal they are tracking. Some users choose to receive updates on a daily or weekly basis" (Curnow, 2005).

- *Global tracking: Track anywhere in the world from a central point.*

  With devices tracking wildlife all over the world it has been proven that the system works globally. Some countries using our devices include, Tanzania, Malawi, Zimbabwe, Mozambique, Kenya and Costa Rica. The device works in any area where an SMS can be sent from a cell phone. In areas with no coverage the data is stored to be downloaded later.

- *Saves money:*

  The cost for the positioning and data transfer module meets the user requirement, making this method of tracking viable. According to Professor Wouter van Hoven at the University of Pretoria's Center for Wildlife Management the system cuts the cost of tracking wildlife by up to 60% (Anon, 2005b). The cost savings are mainly due to no need for human intervention in the field.

- *Capable of downloading at least (24 locations x 64 bytes, i.e.) 1535 bytes of data per day.*

  The GSM network is capable of sending more than 1535 bytes of data per day, meeting the user requirement statement. The device does a check for sufficient GSM coverage before trying to send the data so that trying and retrying to send data waste no energy. In the case of insufficient coverage the device will only store the data to be downloaded on the next timing interval.

- *Geo fencing: Draw no-go zones and be notified when a violation occurs.*

  More than 600 zone violation notifications sent to users, park managers, researchers and farmers proves that geo-fencing adds great value to this tracking system and our clients confirm this. The violations were reported within 30 seconds from the time it was reported by the device on the animal via SMS to the users phone.

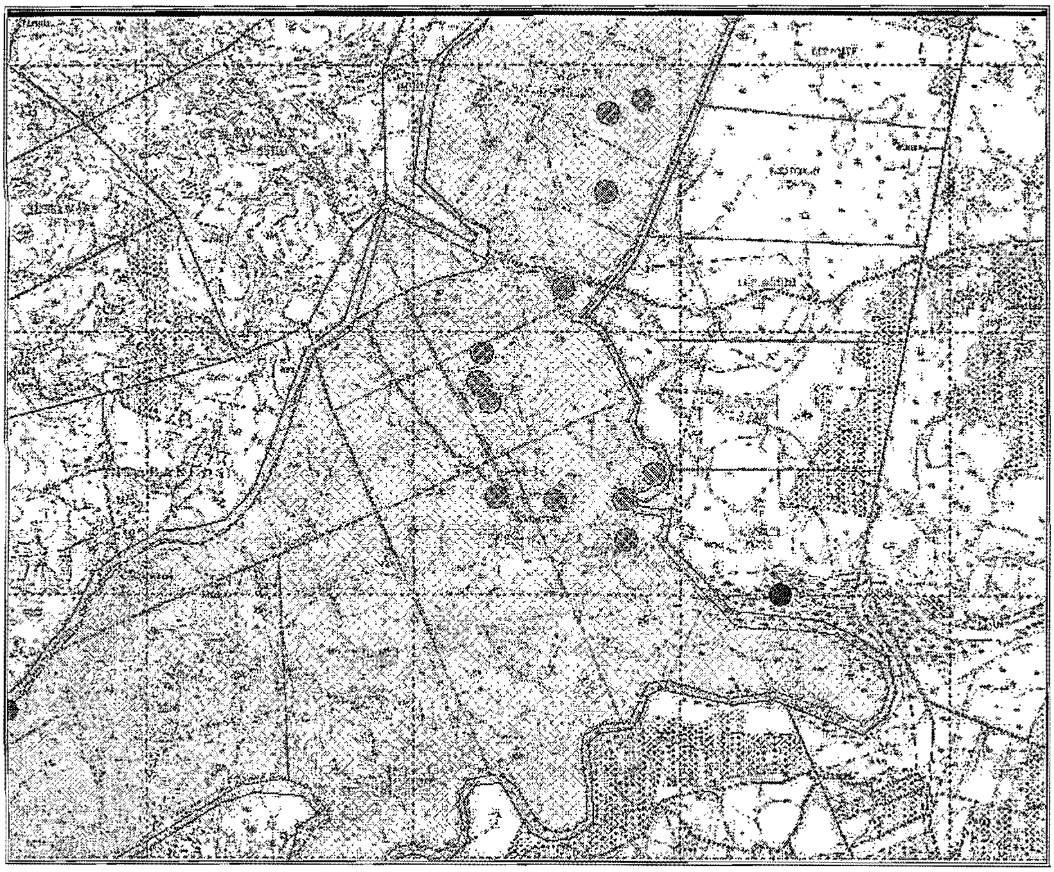


Figure 4 Example of zone violation

- *Tracking from a Cell-phone when in the field.*

  More than 90 000 GPS locations have been reported to user cell phones proving that this feature works and are used very frequently. The following remarks included in the Appendix confirms this fact: “"Haupt said getting a text message from a leopard - or an elephant, cheetah, rhino or lion was increasingly frequent in South Africa” (Curnow, 2005) and “Professor Wouter van Hoven of the University of Pretoria's Center for Wildlife

Management says getting a text message from a leopard is 'a great ice-breaker in the pub.'" (Curnow, 2005). Users can receive this data anywhere in the filed where there are efficient GSM coverage to receive a SMS. The time delay in reporting the new position from the animal to the users is maximum 30 seconds.

- *Easy-to-use interface to download and view the data on a map worldwide.*

  Since the beginning of this study explaining, packaging and presenting the product and technology in an easy to use way was one of our biggest challenges. We get positive feedback from most of our clients and the activity log of users using the system proves this fact. The following remarks included in the Appendix confirm this fact: "Van Hoven said the information also was linked to a secure Web site that has a map on which the GPS coordinates are plotted. From this, Van Hoven said, a pattern of habits and range can be extrapolated from the seemingly random collection of six hourly location coordinates" and "capturing data about the movements and habits of wild animals has never been so easy, it seems" (Curnow, 2005). The position points are displayed in text mode or can be exported to the widely used "Google Earth" mapping software interface by the click of a button.

6.4 Conclusion

The hypothesis states that a new generation wildlife tracking system based on a combination of GPS/GSM technology will be a viable option in the practical management of wildlife conservation establishments in terms of accuracy and costs involved. This method of tracking will also be accepted by research and conservation specialists. The above discussion provides sufficient proof that the user requirement statement as defined in Chapter 2 (2.3) was met by the prototype system. It is therefore clear that the stated hypothesis has been proven to be correct, making GPS/GSM technology a viable option for the practical management of wildlife conservation establishments.

According to recent research by Jansson (2005) and Sundell *et al.* (2006), the advancement in the GPS/GSM technology for wildlife tracking, opens up new dimensions for wildlife research. According to them this method of tracking will become the most cost-effective method for studying animals in areas serviced by mobile phone networks.

By the time this thesis was concluded, over 300 units were successfully deployed on various animals including vultures, baboons, crocodiles, wild dogs, hyenas, leopards, cheetahs, lions, buffalo, sables, rhinos and elephants. These applications of the technology spans across South Africa and other countries such as Botswana, Costa Rica, Zambia and Kenya.

7 Appendixes

7.1 Article one

March 15, 2005

Texting to save Kenyan elephants

http://www.textually.org/textually/archives/cat_sms_and_wildlife.htm

Scientists in Kenya are using text messages to keep tabs on elephants, reports the BBC, "They're fitting the tuskers with special collars that text in their exact location every hour, enabling experts to discover where elephants roam, and use that information to protect them.

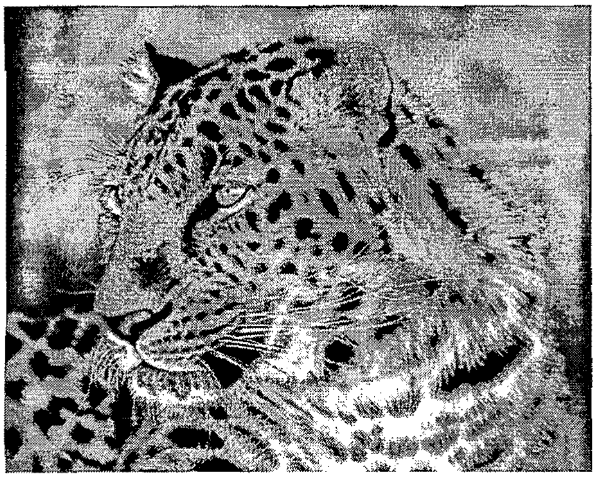
They hope the technology will also be able to warn farmers if elephants are about to trample their crops in future. The scheme is possible because the Africa bush is now part of a growing mobile phone network, with loads of masts covering the countryside."

7.2 Article two

June 20, 2005

Safari by cellphone (By Robyn Curnow International Herald Tribune)

http://www.iht.com/articles/2005/06/19/business/wireless20.php



Professor Wouter van Hoven of the University of Pretoria's Center for Wildlife Management says getting a text message from a leopard is "a great ice-breaker in the pub." Van Hoven is heading up a project that tracks three leopards in the Waterberg region of South Africa's Limpopo Province, using a combination of cellphone and GPS, or global positioning system, technology.

African Wildlife Tracking, headed by Martin Haupt, is the company behind the wireless animal tracking system that Van Hoven is using in his leopard project. Haupt said getting a text message from a leopard - or an elephant, cheetah, rhino or lion - was increasingly frequent in South Africa. Many game reserves or conservation areas have wild animals that are fitted with collared tracking devices.

"The device is fitted around the animal's neck," Haupt said. "On the collar you have batteries, a GPS, a VHF transmitter and a cellphone." The cellphone, he said, is a "no frills" mobile phone about 2 centimeters, or 0.8 inch, long and 3 millimeters thick. "The cellphone enables you to 'talk' to the collar," Haupt said. "You can switch the collar off or on. You can send a message and get the longitude and latitude" of the animal. The collar cellphone can also "turn on" the VHF transmitter, enabling a person to track the animal with directional antennas when out in the bush.

Capturing data about the movements and habits of wild animals has never been so easy, it seems. Van Hoven explained how the technology works for his leopard research purposes: "The collar on the animal is programmed to send out four SMSs a day, every six hours, and that SMS is linked to a GPS, so every six hours the collars register the exact global position of where the animal is. That is then fed to the cellphone. The cellphone then sends the SMS, which is the position information of the animal."

Van Hoven said the information also was linked to a secure Web site that has a map on which the GPS coordinates are plotted. From this, Van Hoven said, a pattern of habits and range can be extrapolated from the seemingly random collection of six hourly location coordinates. Not all users chose to receive data every six hours. Scientists, conservationists and game rangers vary the frequency of the updates depending on what animal they are tracking. Some users choose to receive updates on a daily or weekly basis.

The system even allows the user to "text" the animal directly, requesting immediate notification of its whereabouts, although this is not something Van Hoven does. Haupt, who developed the technology and the software, said this could lead to some unusual text messages. "You might want to know where a leopard or elephant is at that moment," he said, "so you can text 'Where is elephant No. 1?' to the elephant's cellphone." Immediately, the user would receive a reply text message from the elephant giving the longitude and latitude of the animal's location.

If the collar device is not turned on - to save battery power, for example - or if there is no cellphone coverage in the area where the animal is roaming, the collected information is stored and can be downloaded from the Internet using an Africa Wildlife Tracking software package called Hawk105. As many as 240 readings can be stored online, ready to be downloaded as soon as the device is back in range or turned on.

The battery life of the collar depends on the number of readings taken per day. The estimated battery life for five readings a day is two years in a well-covered cellular area. South Africa has some of the best cellphone coverage in the world, Van Hoven said, and that ensures that his leopards are mostly within cellphone range as they roam the dry savannah of South Africa's northernmost province.

Collecting data on where, when and how far wild animals travel helps scientists like Van Hoven gain a better understanding of their habits and numbers. Leopards, for example, are notoriously difficult to spot and track in the wild, so conservationists do not know how many leopards there are in South Africa. Keeping in mobile phone contact might be one way to find out.

7.3 Article three

September 16, 2005

Cell phone technology helps researches obtain information about animals.

http://www.textually.org/textually/archives/cat_sms_and_wildlife.htm

Researchers in Kenya and South Africa are using cell phone technology to gather information on elephants, cheetahs, leopards and other animals, reports Pravda.

"The relatively cheap tracking device includes a no-frills cell phone that is put in a weatherproof case with a GPS receiver, memory card and software to operate the system. The unit, placed on a collar, is then tied around the neck of a wild animal, according to the AP.

As the animals roam, "the GPS receives coordinates, downloads them onto the memory chip, and then every hour, the phone wakes up and sends a text message of the last hour's coordinates to a central server," said Michael Joseph of Safaricom, Kenya's leading service provider, which is involved in an elephant-tracking project.

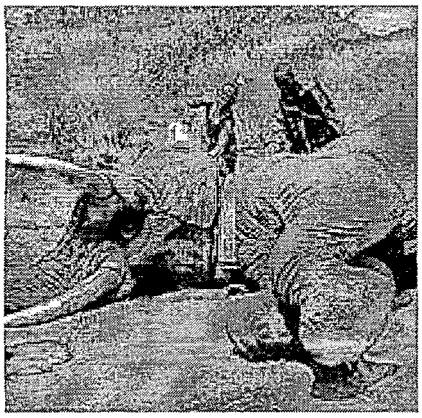
Then the phone goes to sleep again, preserving battery power.

7.4 Article four

October 17, 2005

Cell phone use changes life in Africa

http://www.textually.org/textually/archives/cat_sms_and_wildlife.htm



Africa's cellphone explosion changes economics and society. "We are developing unique ways to use the phone, which has not been done anywhere else," says South African Michael Joseph, chief executive officer of Safaricom, one of two service providers in Kenya. For example, wildlife researchers in Kenya and South Africa have put no-frills cellphones in weatherproof cases on a collar that goes around an elephant's neck. The phone sends a message every hour, revealing the animal's whereabouts, explains USA Today. It cuts the cost of tracking wildlife by up to 60%, said Professor Wouter van Hoven of the University of Pretoria's Center for Wildlife Management.

7.5 Article five

Out of Africa

http://www.textually.org/textually/archives/cat_sms_and_wildlife.htm

Haupt said cell phone technology had revolutionised animal tracking over the past four years and about 200 beasts were now collared with such technology in Africa, including elephants, zebras and baboons. "It's a lot cheaper than using satellites. A reading is the cost of an SMS," he said.

The batteries last longer than those used in the old satellite devices, the system uses GPS tracking and your elephant is just an SMS text message away. "You can type in an SMS 'Where is elephant number 1?' and it will give you its location," he said.

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