A Literature Review of Recent Developments in Bluetooth networking and Animal Tracking and Monitoring.

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Introduction

Technology already tracks or monitors animals, people, vehicles and other objects to eliminate the need for constant human observation. These technologies need to be small, economical and consume a minimal amount of power. Bluetooth technology is being used extensively in hand-held devices and wireless computing [Pico Communications] because of its characteristics mentioned above. This project aims to use Bluetooth technology to monitor and track animals in the wild. More specifically, this project deals with the off-loading of data from a device situated on an animal. The aim of this literature survey is to investigate the Bluetooth technology, focusing on routing in Bluetooth networks, as well as current animal tracking and monitoring technologies.

Current technologies used in tracking and monitoring

Many of these projects make use of the Global Positioning System (GPS), Global System for Mobile (GSM) or directional radio transmission tracking. One of them is described in "Save the Elephants" GSM tracking project, sponsored by Safari.com in Kenya, which makes use of the GPS system to gather locational information of tags placed on elephants [Douglas-Hamilton, I. e*t al (*February 2004)]. These tags also have GSM modules that allow the locational data to be downloaded periodically. Objectives of this project are to develop small tags that have a long battery life, are cheap and light. Before the safari.com project, VHF (Very High Frequency) radio was used to download the GPS data from the animals about every 3 months. Sending data using VHF requires a large amount of power consumption, hence downloads were only done every three months. GSM technology lowers this power consumption enabling more regular data retrieval. Data, such as that elephants usually travel about 10km a day but can walk 30km or more, was collected using this technology. The Kenya wildlife service use this knowledge to plan things like human-animal interaction and fence positioning.

A company called Digital Angle has developed a chip that is embedded into animals [Hostetter, J (April 2003)]. While these chips do not produce locational information, they enable a person to electronically identify an animal as well as get its current body temperature. The company is looking at using these "*bio chips*" to track an animal's blood pressure and hormonal changes [Hostetter, J (April 2003)]. The bio chips are very small and light but data can only be collected with a hand held reader which provides the chip with power via magnetic induction, similar to RFID technology.

Most animal tracking projects are interested in the movements of animals. We are interested in the interaction of animals and possibly data concerning individual animals using the technology being developed by Digital Angle. Because we aim to only use Bluetooth technology (and not GPS), an animal's location could be roughly plotted by tagging physical positions, for example watering holes and trees. The tracking and monitoring systems above use VHF or GSM technologies to download data from animals. We want to look at the feasibility of using Bluetooth networks to download this data. Bluetooth is suited to this application because it is small, light and uses a minimal amount of power, whereas GSM and GPS devices have a short battery life and are large and heavy.

In an application that does not involve animals, Ron Alterovitz from the computer science department at Caltech University in California has done a research project involving message routing over a Bluetooth scatternet. [Alterovitz, R (2001)] His aim was to make wireless-enabled vehicles communicate while in motion. The ad-hoc properties of piconets and scatternets enable the vehicles to pass messages between them while they are in motion. The vehicles were linked up to a positioning system and set to run around in a 1000x1000 cm room. Each vehicle was able to transmit up to a distance of 250cm. The vehicles were left to move around the room randomly while the positioning system and vehicles passed messages amongst each other to stop them crashing. The routing tables, used to pass messages, were only allowed to be updated at set intervals. It was found that message packets were lost if the speed of the vehicles was increased while the routing interval was kept the same [Alterovitz, R (June 2001)].

Although Bluetooth has been used for tracking small autonomous vehicles, there is no evidence of the use of this technology to track animals. However, wireless devices, for example Bluetooth enabled cell phones, could be used to track human beings. This raises ethical and privacy issues [Potter, B (November 2003)].

Bluetooth as the Underlying Technology

The above technologies aim to provide a means of tracking or message-passing through the use of devices that are physically small, use minimal amounts of power and support an ad-hoc type of communication. Bluetooth supports realistic data rates of up to 600Kbps and claims to make a battery last from 50% to 300% longer than other wireless technologies [PicoCommunications, (November 2002)]. There are two classes of Bluetooth device. The class 2 radio allows a range of ten meters while class 1 radios allow for transmission over 100 meters. Bluetooth operates in the license-free 2.4GHz band making use of frequency hopping at a rate of 1600 hops per second.

Although Bluetooth has limitations in its transfer speed and communication distance, its market share is rising while 802.11 (WiFi) has slowed down in its growth [Dursch, A. *et all* (December 2003)]. The rising interest in Bluetooth will increase production, causing the already cheap technology to become easily obtainable.

The Bluetooth stack

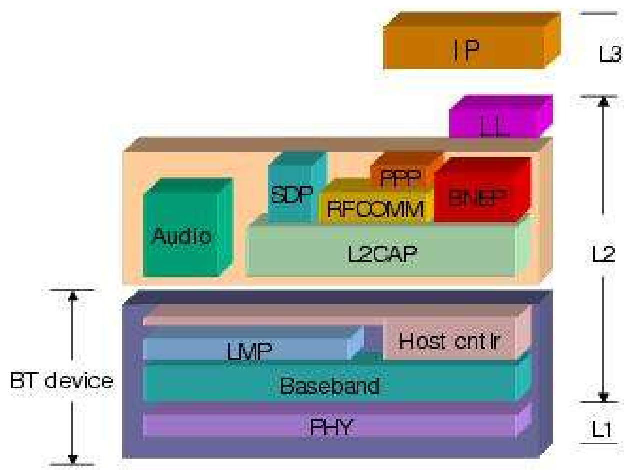

Illustration 1The Bluetooth Stack

Each Bluetooth packet has a fixed format that starts with a 72-bit access code. This is followed by a 54-bit header containing error correction, retransmission and control information. Finally the packet contains a payload of 0 to 2745 bits. Three methods, Forward Error Correction (FEC), Automatic Repeated Request (ARQ) and Cyclic Redundancy Checks (CRC) are used for error correction during Bluetooth communication [Forum Nokia (April 2003)].

This project is interested in the following Bluetooth stack layers:

The Link Manager Protocol (LPM) layer is responsible for setting up the links between Bluetooth devices and deals with master/slave switching, low power modes, clock offsets and packet size negotiation. This layer, although not critical to this project, also handles the exchange of authentication and encryption information. The Logical Link Control and Adaptation Protocol (L2CAP) enables multiplexing of the protocols above it by segmenting and reassembling packets [Pico Communications inc]. The Service Discovery Protocol (SDP) enables Bluetooth devices to advertise and discover services. SDP passes bitmasks, representing advertised services, to all backbone nodes. This allows other devices to discover the type and location of a service on a Bluetooth network quickly [Nordbotten, N, A. *et al* (2004)]. RFCOMM is a serial port emulation protocol enabling RS232 control and data signaling over Bluetooth. It allows services such as the Point to Point Protocol (PPP) to be used over Bluetooth. IP is the standard protocol used on the Internet [Pico Communications inc].

Bluetooth profiles

Bluetooth profiles describe the main usage models of Bluetooth. The current Bluetooth specification contains four general profiles. [Forum Nokia (April 2003)] The Generic Access Profile defines the discovery of other Bluetooth devices, link management and connectivity, security levels and common format requirements for user interfaces. All Bluetooth devices have to support this profile and all other profiles require and use it. The Service Discovery Application Profile defines procedures for a Bluetooth application to discover services advertised by another Bluetooth device, and should be followed should this project make use of services during implementation. The Serial Port Profile defines the Bluetooth requirements for setting up emulated serial cable connections. This profile is also an option should this project transfer data over RS232 connections. The Generic Object Exchange Profile is used by applications that need object exchange capabilities. This profile is also an option should we want to model our data as objects and pass these objects from device to device and then finally to a data sink [Forum Nokia (April 2003)].

Ad-Hoc Bluetooth Networks

Bluetooth enabled devices form ad-hoc networks when they come into contact with one another. These networks are built using scatternet and piconet formation algorithms as described by [Law, C. *et al* (2001)]. Between 1 and 7 devices can form a piconet. One device is designated to be the master. This decision is made by each device generating a random number determining whether the device will assume to be the master and seek slaves or assume to be a slave and scan for the master. Because only 7 nodes are allowed to participate in a piconet, scatternets are formed by linking many piconets together via shared slave nodes. The number of piconets to which a device belongs is termed its degree. A master node in a piconet may only have a degree of one, meaning a master node may not be shared between two piconets. The shared slaves are time multiplexed between the piconets to which it belongs and data sent between the piconets must be sent via the shared slave [Law, C. *et al*, (2001)]. The time it takes for data to be passed through a shared slave is dependent on the manner in which the shared slave switches between piconets. Shared slaves need to have timed rendezvous points with piconet masters in order to exchange data [Mišić, J. *et al* (February 2004)]. The masters and shared slaves are collectively referred to as back bone nodes of the formed scatternet. The piconet and scatternet formation algorithms allow nodes to move and migrate between piconets and allow small piconets to be merged [Law, C. *et al* (2001)].

These ad-hoc properties of piconets and scatternets enable data to be exchanged between many Bluetooth devices while those devices are moving between piconets within a scatternet, effectively enabling the devices to physically move around while data is being exchanged amongst them.

Conclusion

This literature search has found no evidence that Bluetooth has been used to track or monitor animals in the wild. It has however found many applications where Bluetooth networks have been used for mobile devices needing to exchange data. The literature shows that there is a need for small, inexpensive animal tracking devices that consume a minimal amount of power. It is also shown that Bluetooth is already being used for hand-held and mobile computing applications for these same reasons. Our aim is to build upon the device and network technologies surveyed in this paper, to determine the feasibility of a Bluetooth-based animal tracking and monitoring system, which has a low degree of human probe effect.

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