Design of an ad hoc wireless network for animal tracking and environmental management

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***Abstract*—This paper discusses the concept design and preliminary results on the implementation of an ad hoc network for wildlife telemetry tracking. The design problem overview is given, as well as background on ad hoc networks. A detailed link budget is calculated using the Radio Mobile software. The paper then continues to describe constraints in the design of the network and evaluates MAC and routing protocols for implementation. A design methodology is stipulated for the mathematical modelling and simulation of these protocols.**

I. Introduction

The multi-hop characteristic of ad hoc networks makes it a viable solution to wildlife telemetry tracking for extending the area of coverage in a wireless network. Not only does it extend the area that can be covered, but it also provides the ability for nodes to be mobile or nomadic. Thus accommodating wildlife researchers in being able to move network nodes, as wildlife walking patterns changes or research objectives changes. Wireless networks however have several design constraints that should be considered. One of these being interference in the wireless transmission channel such as topography and vegetation of the specific area that should be covered by the network. Another consideration is in the routing algorithm that governs the information flow to the intended station. In this paper the considerations are taken into account when determining the theoretical performance of an ad hoc wireless network for the application of wildlife telemetry tracking in the Cederberg mountain area.

The rest of this paper will proceed as follows: Section II gives a brief background on the design problem at hand. Section III discusses the link budget. Section IV describes the chosen protocols for implementation. Section V details the modelling and simulation process. The paper is concluded in section VI

II. Design Problem Overview

The emphasis is placed on the design of a network for the Cape Leopard Trust to monitor leopard data (GPS coordinates and temperature) received from collared leopards and single frame pictures from leopard trap cages. This data will then be relayed to a base station via multiple hops. The network nodes will be nomadic, rather than mobile, meaning that it won't be moved on a daily basis. In the event of a researcher moving a node, the network must be able to reconfigure itself because of a change in topology. Thus also implying self-healing, should a node be switched off or failure due to power drainage .

An area of roughly 2400 km^2 should be covered by a minimum number of nodes, however the network should be scalable up to 13 monitoring nodes.

ICASA stipulates the 148 to 152 MHz band as the wildlife telemetry tracking band[1]. The design resides thus to a VHF network which implies low data rates as opposed to GSM or GPRS.

III. Link budget calculation

The link budget is based on the transceiver module (used by the leopard collar), from radiometrix[2] with the following specifications: operating frequency : 151.3 MHz, max transmit power : 500mW = 27dBm, receiver sensitivity : -115dBm (for 1ppm bit error rate), data rate : 10kbps. A rough first estimate to determine the maximum propagation distance, using free space propagation, predicts a communication distance of 280km; thus neglecting attenuation due to scattering and obstacles such as trees and hills in the line of sight path. It is however a very difficult task to predict link quality using a mathematical approach taking terrain characteristics fully into account[3]. A great tool for taking into account the topography and vegetation of the area, is Radio Mobile[4], designed by Roger Coude. This software uses Digital Elevation Model (DEM) files, which is a digital representation of ground surface topography or terrain. Figure 1 shows a combined cartesian coverage plot, generated by Radio Mobile for the study area. The signal strength is greatest in the red areas, whereas the white spots shows areas of no coverage. The other colors indicates signal strength inbetween. It is thus predicted that the network with 13 monitoring nodes, 2 relay nodes and the base station, will be able to provide coverage to leopard collars dwelling in more than 90 percent of the study area.

IV. Protocol Strategy

Using the Open Systems Interconnection (OSI) model as reference, the three lower layers of the model is implemented in this design. The physical layer (1) implements frequency shift keying (FSK) modulation as a built-in function from the chosen transceiver module. The data link layer should implement a medium access control algorithm. The two main strategy types being Round Robin and Contention. The superiority of the contention protocol, Carrier Sense Multiple Access (CSMA) over Round Robin Polling (RRP) is clearly shown in [5] for low to medium loading. Considering the application

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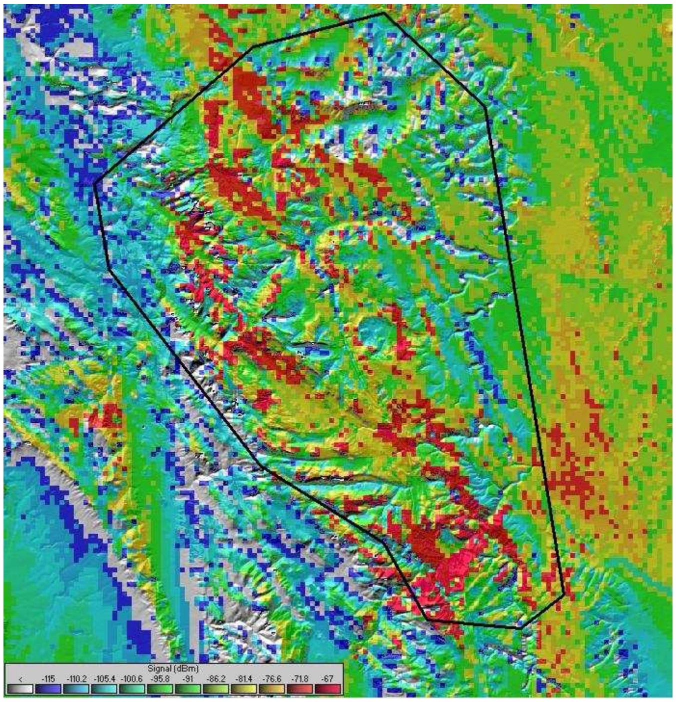

Fig. 1. Combined cartesian coverage plot of study area

at hand to be one with low loading, and in keeping with the 802.11 specification, CSMA with Collision Avoidance (CA) is chosen as the Medium Access Control (MAC) protocol. The routing protocol however has to be designed for the specific scenario.

The major considerations when designing a routing protocol are: [6]

- resource constraints
- error-prone channel state
- hidden and exposed terminal problems
- routing loops
- mobility of nodes

The idea is to use an existing routing protocol as baseline for future enhancements. Many ad hoc routing protocols exists, which can be modified or even combined to design a new hybrid protocol for this specific application.

V. Theoretical modelling and simulation

A. Theoretical modelling

Queueing theory is generally used to determine queue lengths and latency for MAC protocols. This network lends itself to be modelled as a simple M/M/1 queue (One server, Markovian arrival and service distribution). There is however the multi-hop characteristic to the network, which can be simplified by Jackson queueing theory. This states that the total latency is the sum of the latencies at each station[7]. The arrival and service rate can be safely assumed to be Poisson distributed, as the arrival of a leopard in a certain area is totally random. The arrival rate however has to be guessed, as there is no quick way to determine the behavior patterns of leopards. The results from the mathematical model will then be used as verification for the simulation results.

B. Simulation

As stated before, nodes will be nomadic. This might lead to biassing towards a table-driven, rather than an on-demand type of routing protocol. Being nomadic means that tables won't have to be updated as regularly as with mobile nodes, leading to less control traffic. A dynamic routing protocol might prove to generate more control traffic than a nomadic table-driven node. It is thus proposed to simulate and evaluate each protocol to find the best solution. The Ad Hoc On-Demand Distance-Vector (AODV) protocol and the Destination Sequenced Distance-Vector (DSDV) routing protocols will be evaluated on the basis of control overhead generated to find a path to the destination. Simulation will be done in the Omnet++ discrete event simulator with the Mobility Framework. This framework implements the support for node mobility, dynamic connection management and a wireless channel model[8].

VI. Conclusion

It was predicted that more than 90 percent of the study area can be covered by the network. The preliminary proposals for protocols to be implemented were laid out. Future work will involve the simulation of these protocols and the implementation thereof in hardware, to determine the feasibility for using an ad hoc network for wildlife telemetry tracking.

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