ESTABLISHMENT OF A WIRELESS MESH NETWORK AND POSITIONAL AWARENESS SYSTEM IN A MARS ANALOGUE ENVIRONMENT. Thomas W. Clardy[1] K.E. Fristad[2] J. C. Rask[3] C. P. McKay[4]. [1]1148 Galway Court, Hummelstown, PA 17036, thomasclardy@gmail.com, [2]Goddard Space Flight Center in Greenbelt, MD 20771, [3]Enterprise Advisory Services Incorporated, NASA Ames Research Center, Moffett Field, CA 94035, [4]Space Sciences Division, NASA Ames Research Center, Moffett Field, CA 94035.

Introduction: While access to positional awareness information is readily available on Earth through the Global Positioning System (GPS), no such system exists today on the Moon or Mars. It is anticipated that reliable, accurate, and ubiquitous positional awareness will be necessary to meet the future scientific and logistical requirements of field operations on the surface of other planetary bodies. Therefore, rovers and astronauts must also be equipped with communication capabilities that provide real-time information on location, heading, and rate of travel. Such a network must handle the data communications needs between remote sensors, rovers, roving transport vehicles, astronauts on extravehicular activity (EVA), and fixed structures. Our work focuses on the development of a wireless mesh network constructed from commercial off-the-shelf (COTS) hardware and COTS software to provide positional awareness, which is independent of GPS, in the field over this network.

This project demonstrates the ability and examines the effectiveness of providing geospatial positional awareness information for every node on a wireless mesh network (WMN). It is anticipated that any communications network will require at least one centralized backhaul connection to Earth. In the case of a WMN, each node of the network will have the capability to communicate directly with every other node within its range. Each node will also serve to relay communications to every other node and eventually to the backhaul connection, thereby creating a wireless mesh network. This design reduces power requirements on individual nodes and allows the network to be extended in dynamic ways to support communications on long range EVAs beyond the horizon.

Background: To test such a system, members of Spaceward Bound Crew 52 configured, deployed, and tested a wireless mesh network at the Mars Desert Research Station (MDRS) near Hanksville, Utah using entirely COTS hardware [1]. This test network was constructed to cover an approximately one-kilometer radius. A +18dB omni directional antenna was permanently affixed atop the Habitat Module (Hab). This was powered by a 500mW amplifier connected to a 802.11g router. Three other 802.11g access points (APs) were distributed in elevated areas surrounding the Hab. These APs were connected to 802.11g wireless Ethernet bridges giving them relay capability thereby creating a mesh network. A variety of omni-directional, directional, and highly directional antennas were used to cover the area and examine the specific absorption rate of the elevated landmasses in the test area around MDRS. The system was tested for suitability of passing data over the link at various ranges.

The Ekahau Real-Time Location System (RTLS) was configured, calibrated, and tested on this network. The Ekahau (RTLS) "uses the received signal strength indicator (RSSI) as the basis for positioning and a probabilistic framework for estimating the location of the tracked item. The framework compares the received RSSI values with the values stored in the Positioning Model to determine the location of the device" [2]. Multipath from elevated land formations was anticipated to play a role in both link quality coverage availability and in the Ekahau (RTLS) positional accuracy level.

During testing, the isolated desert environment was devoid of significant 2.4Ghz background noise. Atmospheric losses were mitigated by very low humidity. Temperature was 8°C and moisture in the first few centimeters of soil was low.

Methods: The following equations were used in this study:

Transmit[dBm] = Transmit power[dBm] <MINUS> cable loss[dB] <PLUS> antenna gain[dBi]

Propagation[dB] = Free space loss[dB]

Receive[dBm] = Antenna gain[dBi] <MINUS> cable loss[dB] <MINUS> receiver sensitivity[dBm]

IF Sum Transmit <PLUS> Sum Propagation <PLUS> Sum Receive = >0 THEN Link is good.

Results:

Network Signal strength samplings demonstrated uniform line of sight (LnOS) coverage to the theoretical maximum ranges of client devices. Signal distances of several kilometers can be achieved in point-to-point scenarios with directional antennas. Communication distances of up to 1km LnOS were achievable point-to-multipoint.

The influence of multipath was examined by illuminating a Morrison Fm. elevated landmass with a +24dBi antenna powered by a 100mW radio. Distance from antenna to formation base was 240 meters. The +8dBi omni-directional receiving antenna was placed 320 meters from the base of the formation, 80 meters behind the transmitting antenna. Reflected total distance was ~580 meters, taking into account the slope of the landmass. Average receiving results over 180 seconds were –88dB, approaching the receivers sensitivity threshold to maintain a quality useable link.

For comparison, free space results for 580 meters distance were obtained and averaged for the same time duration and were –47dB. The theoretical maximum for the distance of 580 meters (with the +24dBi and +8dBi antennas, 1dB combined cable loss, and radios with –92dBm sensitivities) is –42.57dB. An approximation of the rear leakage from the transmitting antenna was sampled by aiming the transmitting antenna into free space and measuring signal strength 80 meters behind the antenna. Signal strength was measured to be –84dB, providing a consistently useable link.

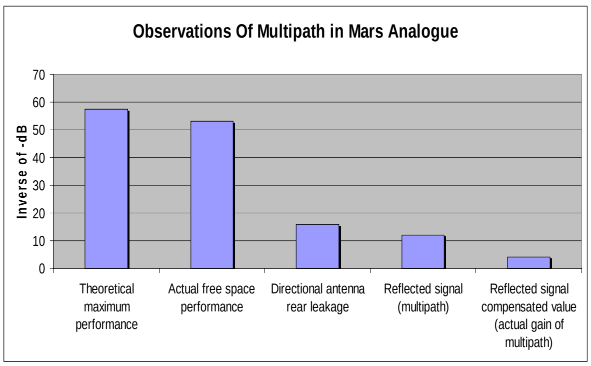

Fig. 1 Signal measured around MDRS.

Positioning Engine The Ekahau RTLS software was configured, a location map was generated, calibration points were taken, and the software was tested. The Ekahau RLTS software supports any 802.11 compliant device as well as Ekahau T201 Wi-Fi tags. The small Wi-Fi tags were attached to crewmembers and assets, and their position was tracked on the software engine in real time. Laptops with the Ekahau client were also tracked. The positioning engine worked throughout the test area without incident. The internal antenna of the T201 Wi-Fi tags provided a positional fix in all but the weakest signal strength areas. A link was maintained until overall signal strength dropped to less than approximately –74dBi as measured on a zero-gain omni-directional antenna.

Discussion and Summary: Near line-of-sight was proven to be a requirement for a usable link. The positioning model requires reception to at least 3 access points. These results show that while some multipath reflection can be expected, local soils or rock may not be sufficiently dense to create a strong multipath environment, perhaps a detriment for MIMO radios and a consideration for highly contrasting topographic theaters of operation. Line of sight is best achieved by positioning radios at high elevations or on crater rims. A redundant, fault-tolerant, self-healing, decentralized, data communications network with low power requirements will be required to support the future scientific and logistical requirements of field operations on the surface of other planetary bodies. Following this model, a wireless mesh network is an ideal candidate for fundamental lunar and martian infrastructure.

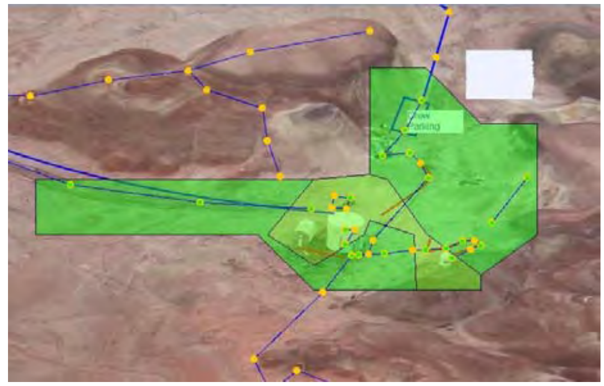

Fig. 2 A screen shot of the positional awareness model tested at the Mars Desert Research Station.

A WMN located on crater rim at the lunar south pole could be powered nearly continuously by solar panels [3] providing ground based communications and positional awareness for landers, rover and humans while reducing the power/mass requirements for onboard communication devices. Easily expanded or descoped as needed, the WMN and backhaul station can provide data storage and a muli-device accessible link to Earth or the limited coverage of orbiters. A WMN is a critical tool for the evolution of planetary exploration from landers and rovers through human exploration and settlement.

References: [1] Field Testing of the WiFi system at MDRS, http://www.marsstuff.com/mdrs/fs06/1205/ [2]Ekahau: Comparison of Wireless Indoor Positioning Technologies (2005) An Ekahau Whitepaper ,Ekahau, Inc. www.ekahau.com [3] Fristad, K.E. et al. (2004) LPSC XXXV #1582.

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