Alternative Communication Networking in Polar Regions

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Presentation Outline

- Motivation
- Introduction
- Multi-Channel Iridium System
- Long range WI-FI System *(work done by Nandish Chalishazar)*
- Field Experiments and Results
- Conclusions

Motivation

- **Polar Radar for Ice Sheet Measurements (PRISM) :**– developing intelligent remote sensing technology to determine thickness of ice sheets and ice-bedrock interface in Greenland and Antarctica. The system comprises of a sensor web deployed over intelligent rovers.

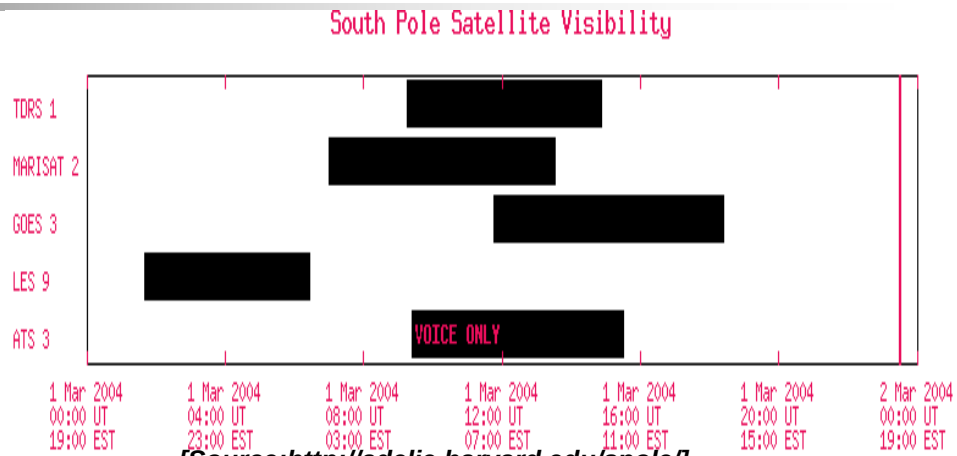
- **Inter-rover communication**
  - Reliable, high bandwidth communications required between nodes separated by 8 Km on the ice

- **Data communication between the field camp and University of Kansas**
  - Data telemetry and access to University and web resources from field
  - Public outreach

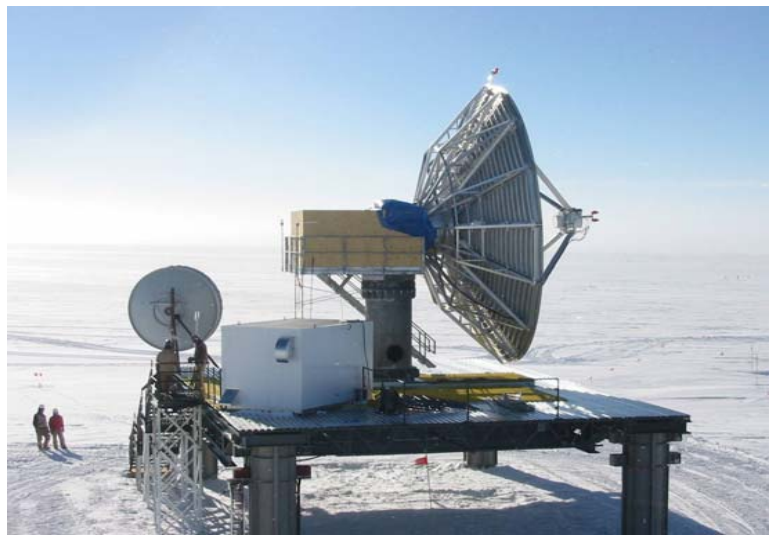
- **Generic data communication for Remote field research**
  - Mainstream communication system for polar science expeditions, field camps in Arctic/Antarctic and other research purposes
  - Government and security use

Introduction – Satellite Communication

- Polar regions do not have conventional communication facilities and are not serviced by most of the major broadband satellite systems (like Inmarsat, Intelsat, Globalstar).
- NASA satellites like ATS3, LES9, GOES, TDRS 1,and MARISAT2 provide broadband access to Polar Regions
- Geo-synchronous, they have a limited visibility window at Poles – typically 10-13 hrs/day.
- High satellite altitude and low elevation angles (1-2^0) result in extremely large field equipment.
- May not be readily available



[Source:http://adelie.harvard.edu/spole/]



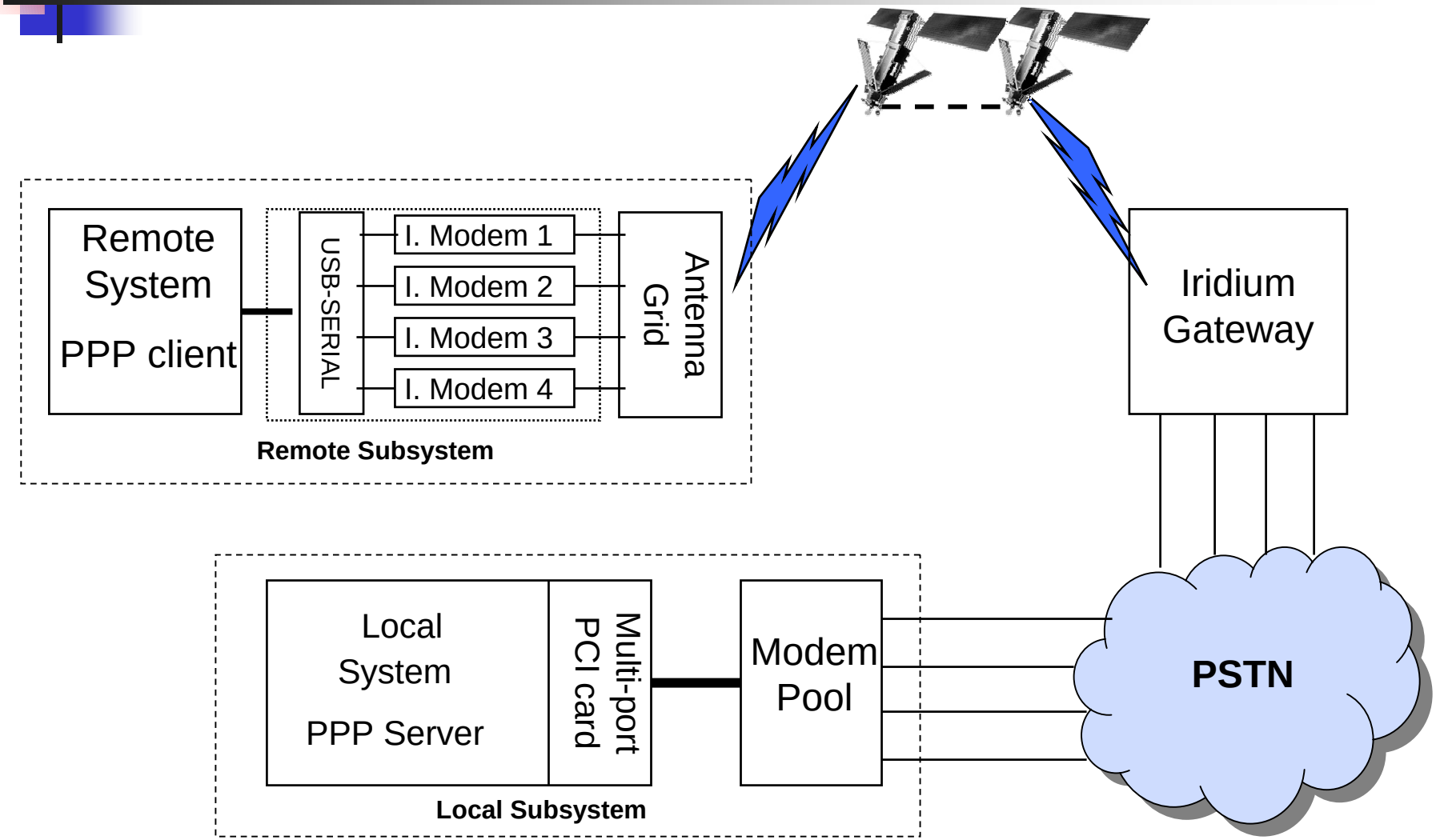
20 m diameter Marisat/GOES antenna at South Pole

Source: http://cfa-www.harvard.edu/~aas/SPUC/02/presentations/SATCOM.ppt

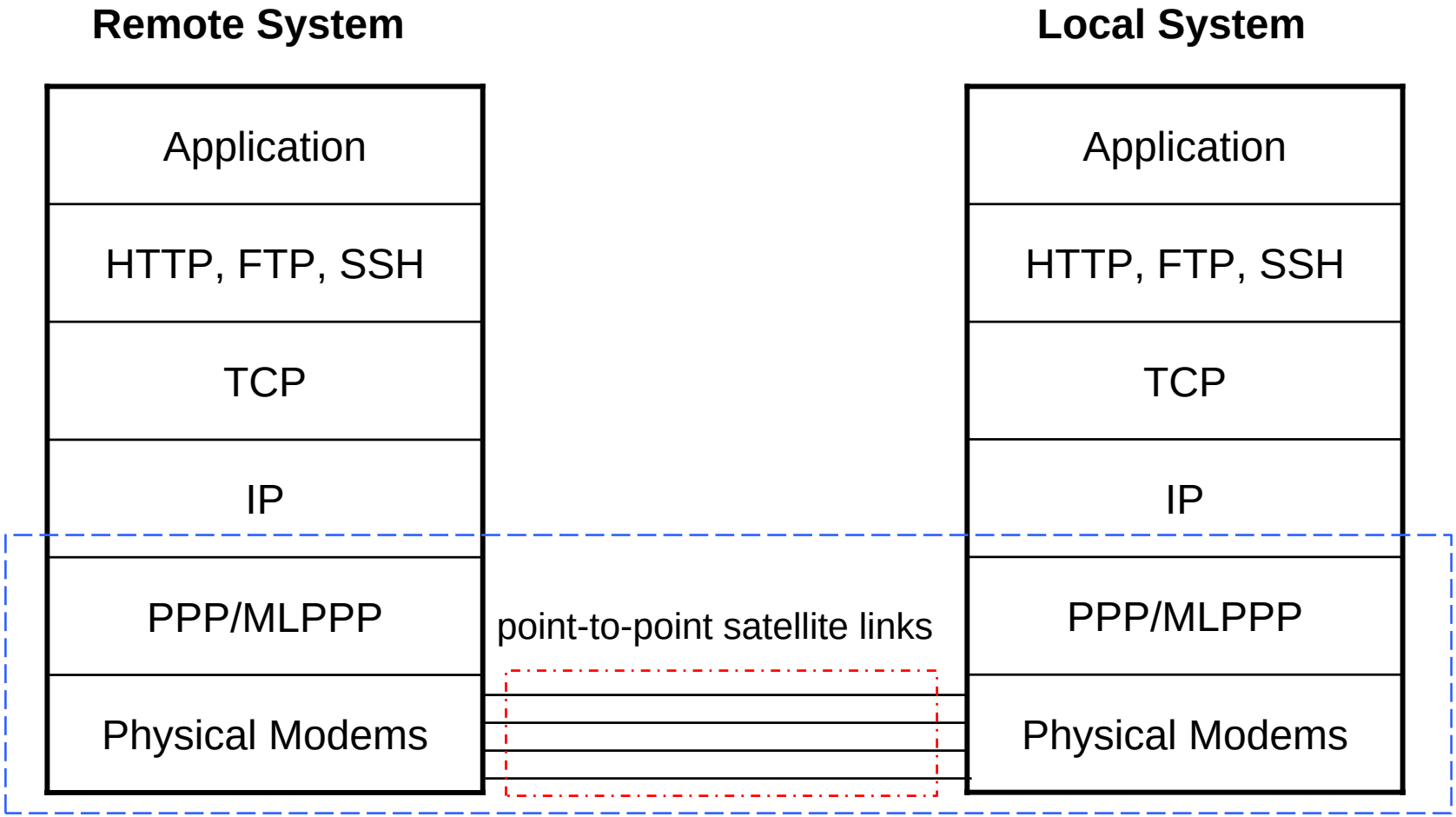
Introduction - Iridium Satellite System

- **Iridium**
  - The only commercial satellite system with true pole-to-pole coverage
  - 66 low earth orbiting (LEO) satellites
  - Onboard satellite switching technology
  - Minimum elevation angle of 8.2^0
  - Average satellite view time ~ 9-10 minutes
  - Access scheme is a combination of FDMA and TDMA
- **Problem:** Since it provides a low bandwidth of 2.4 Kbps, it is not practical to be used as a main stream/ life-line communication system
- **Solution:** Inverse Multiplexing - Combine multiple satellite links using multi-link point to point protocol (MLPPP) to obtain a single logical channel of aggregate bandwidth

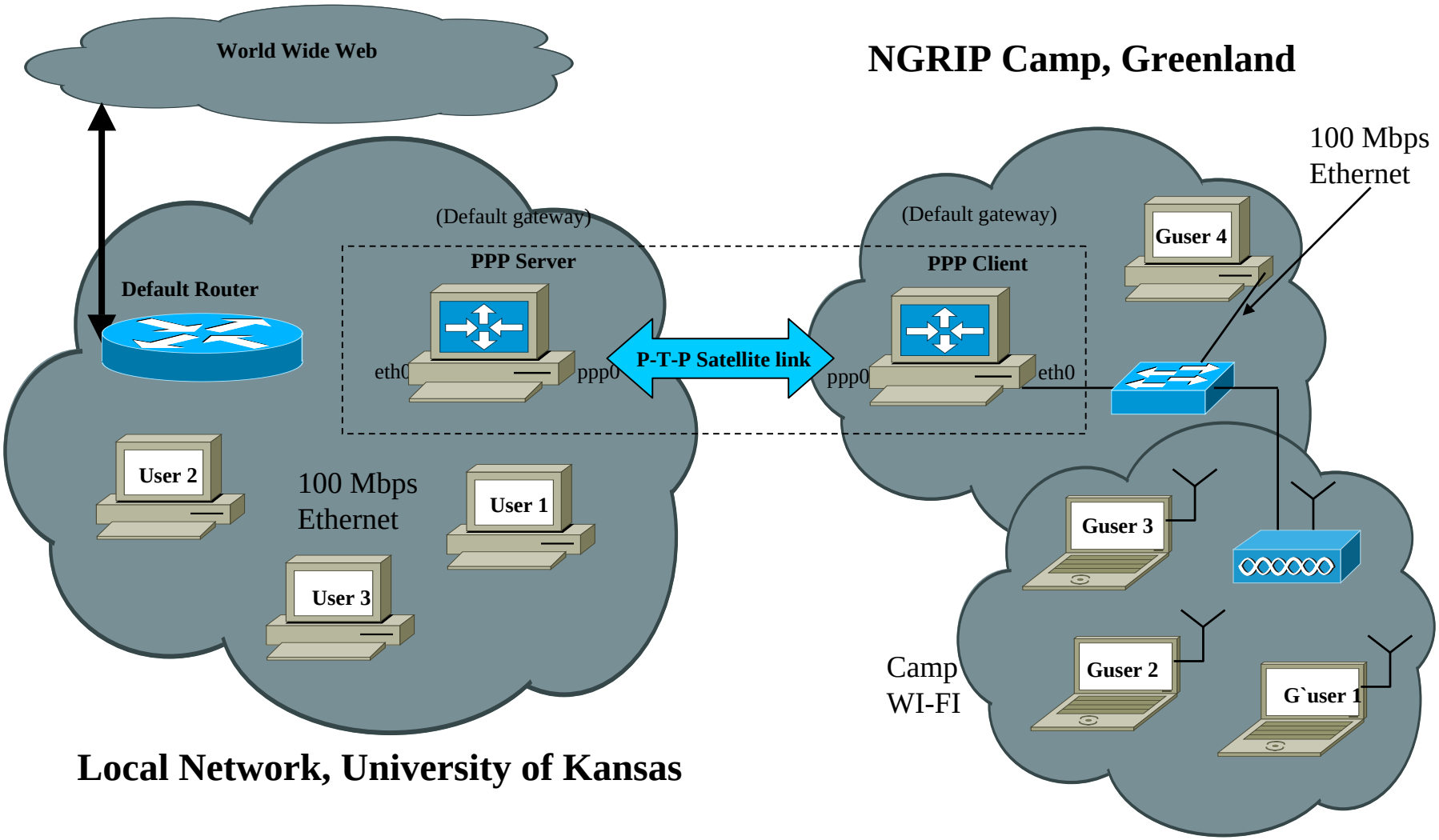
Multi-channel Iridium System - Design



Multi-channel Iridium System – Protocol Stack



Multi-channel Iridium System – Network Architecture

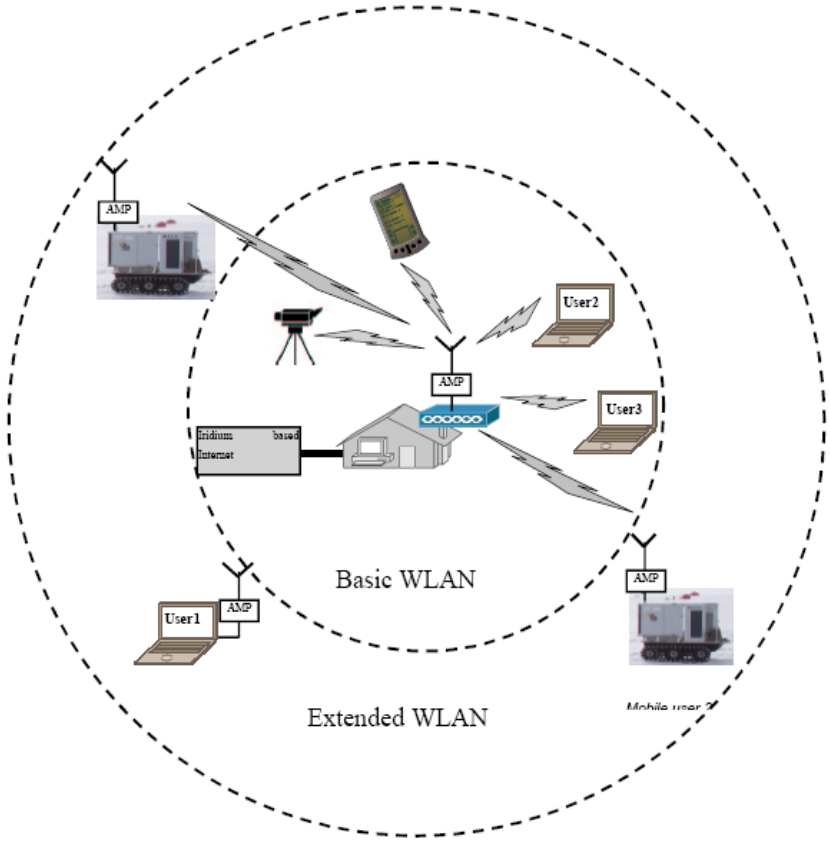


WI-FI system

- Range of the commercial off-the-shelf systems is few hundred meters – not enough
- Increase the range of the 802.11b link up to 8 Km - amplification of the signal is required to overcome the propagation losses
- The two ray propagation model predicts forth power loss with distance over ice
- Also the received signal strength increases by 6 dB on doubling the height of the antenna
- Combination of high gain antenna and RF amplifier can help to achieve the required signal strength
- 9-dBi vertical collinear antenna – horizontal beam width of 360^0 and vertical beam width of 7^0.
- 1-Watt bidirectional amplifier with AGC and Tx of 29.3 dBm

WI-FI System

- **Basic LAN**
  - Central Access point with high gain antenna and bidirectional amplifier
  - End users use off-the-shelf 802.11b wireless cards to access the Iridium based Internet
  - Range ~ 1 Km
- **Extended LAN**
  - Both ends of the communication antennas need amplifiers and high gain antennas connected to the wireless cards
  - Range ~ 8 Km
  - Bandwidth decreases with distance

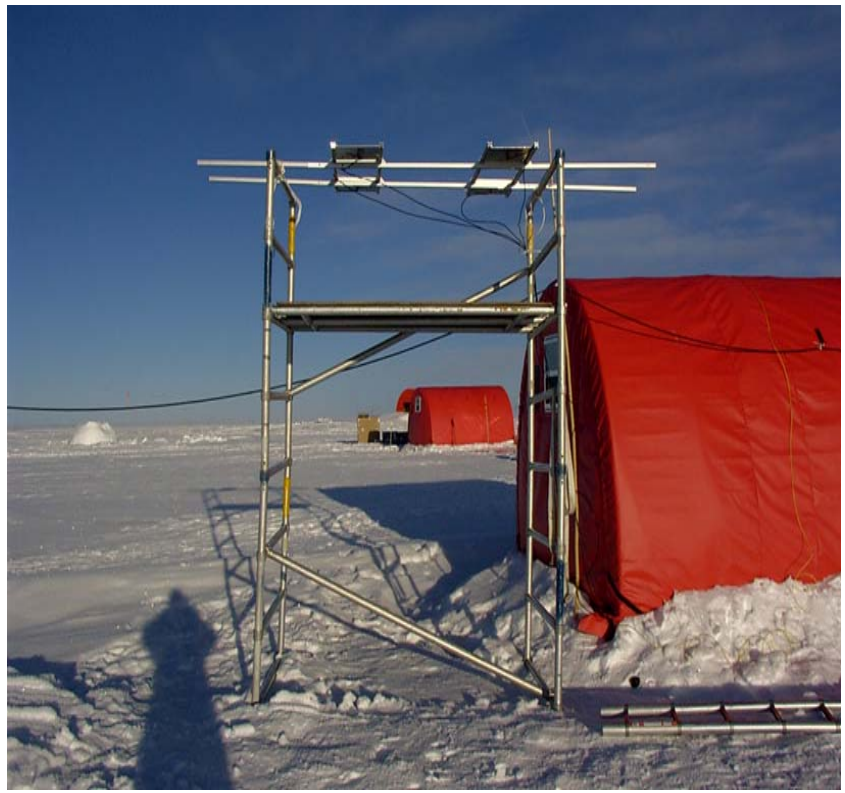


Field Experiments – Iridium System

- Field experiments conducted at NGRIP, Greenland (75° 06' N, 42° 20' W) in Summer 2003

4-channel system setup

Antenna Setup



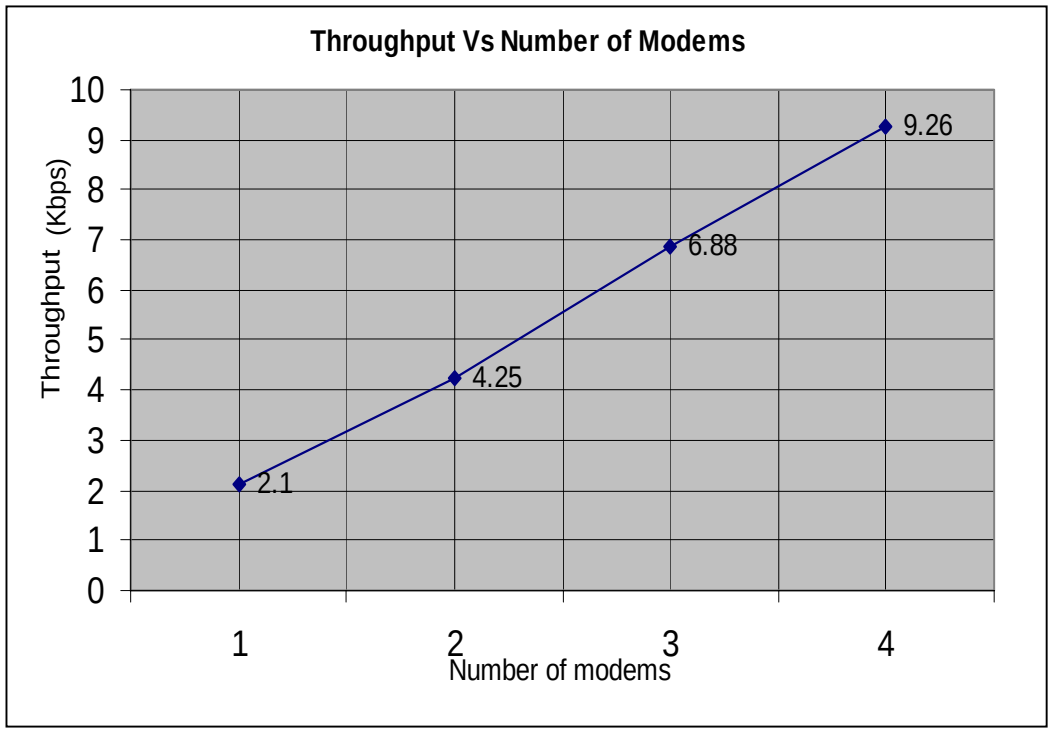
Iridium Results – Delay and Loss Measurement

- Ping tests between the two machines at the end of the of satellite link
- Transmission + Propagation delay = 524msec
- Test results show an average RTT delay of 1.8 sec,
- Random delay variation and high mean deviation
- Causes may include - inter-satellite switching, processing at the gateway, distance between the user and satellite and distance between the satellites (ISL)

Packets sent	Packets received	% Loss	RTT (sec)			
			Avg	Min	Max	Mdev
50	50	0	1.835	1.347	4.127	0.798
100	100	0	1.785	1.448	4.056	0.573
100	100	0	2.067	1.313	6.255	1.272
200	200	0	1.815	1.333	6.228	0.809

Iridium Results – Throughput

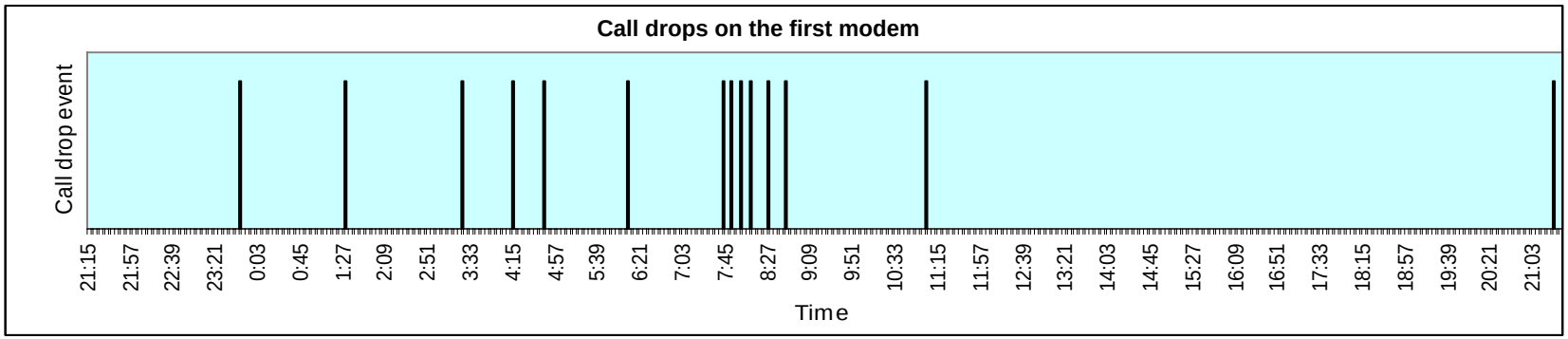
- Tools used – TTCP, IPERF
- Throughput varies to some extend due to RTT variation
- Efficiency > 90%



Effective throughputs during large file transfers

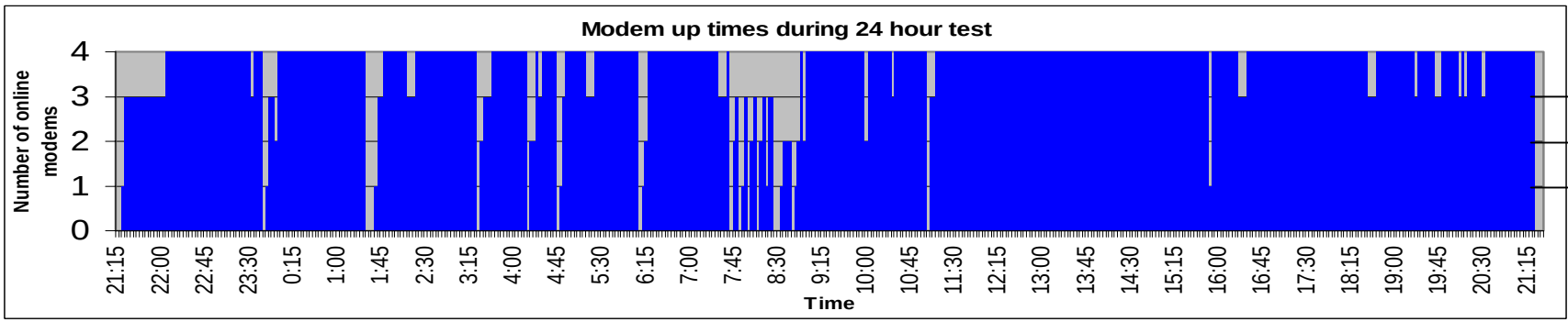
File Size (MB)	Upload Time (min)	Throughput (bits/sec)
0.75	11	9091
1.5	28	7143
1.6	23	9275
2.3	45	6815
2.5	35	9524
3.2	60	7111

Iridium Results – Reliability: 24 hr test



Total :

13 Call drops

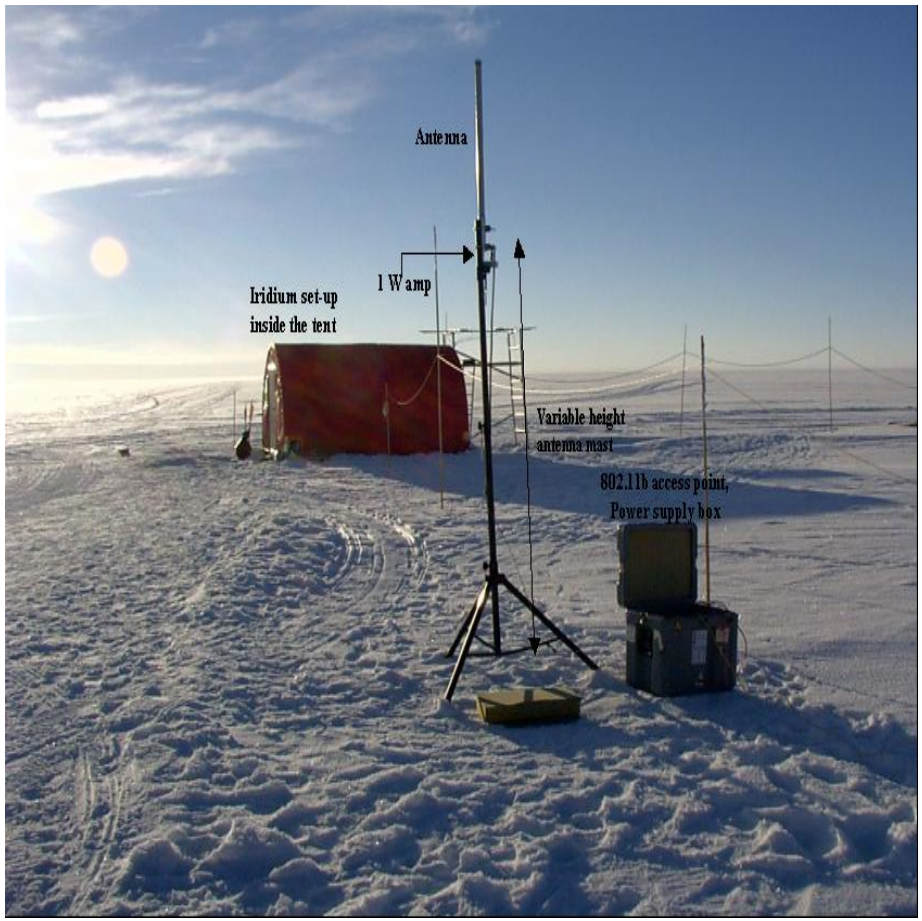


Uptime %
80.6
91.8
94.7
96.8

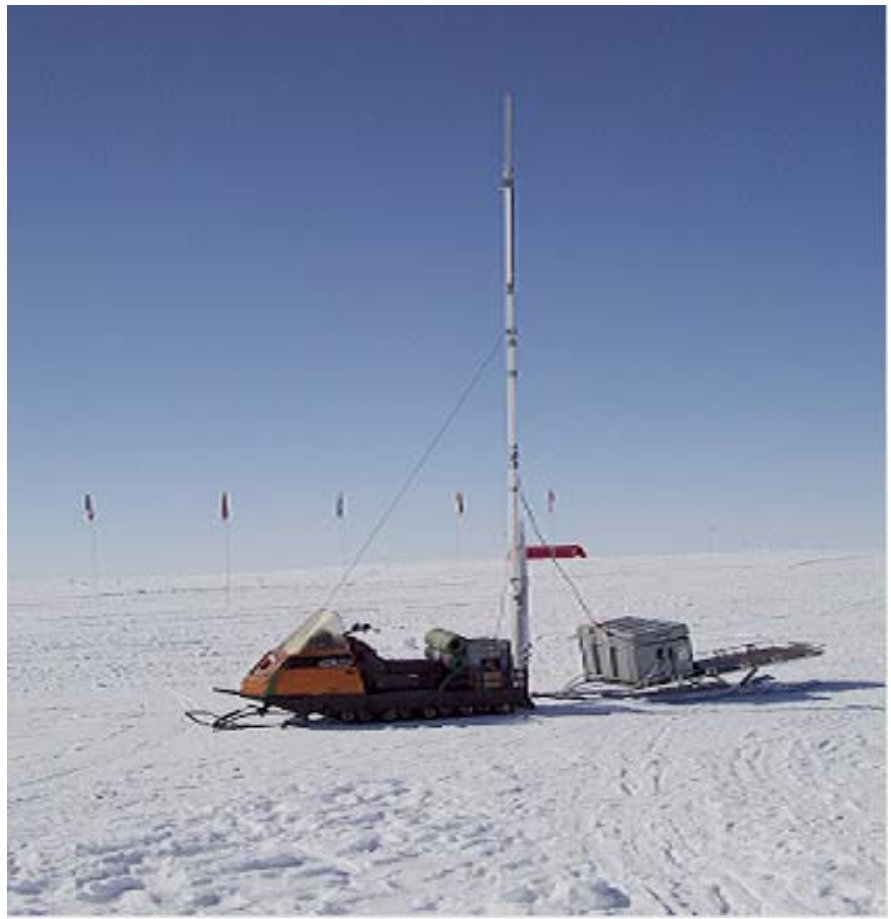
Time interval between call drops (minutes)	146	106	114	50	25	84	89	8	7	7	17	11	137	618

Field Experiments – WI-FI System

Base Station

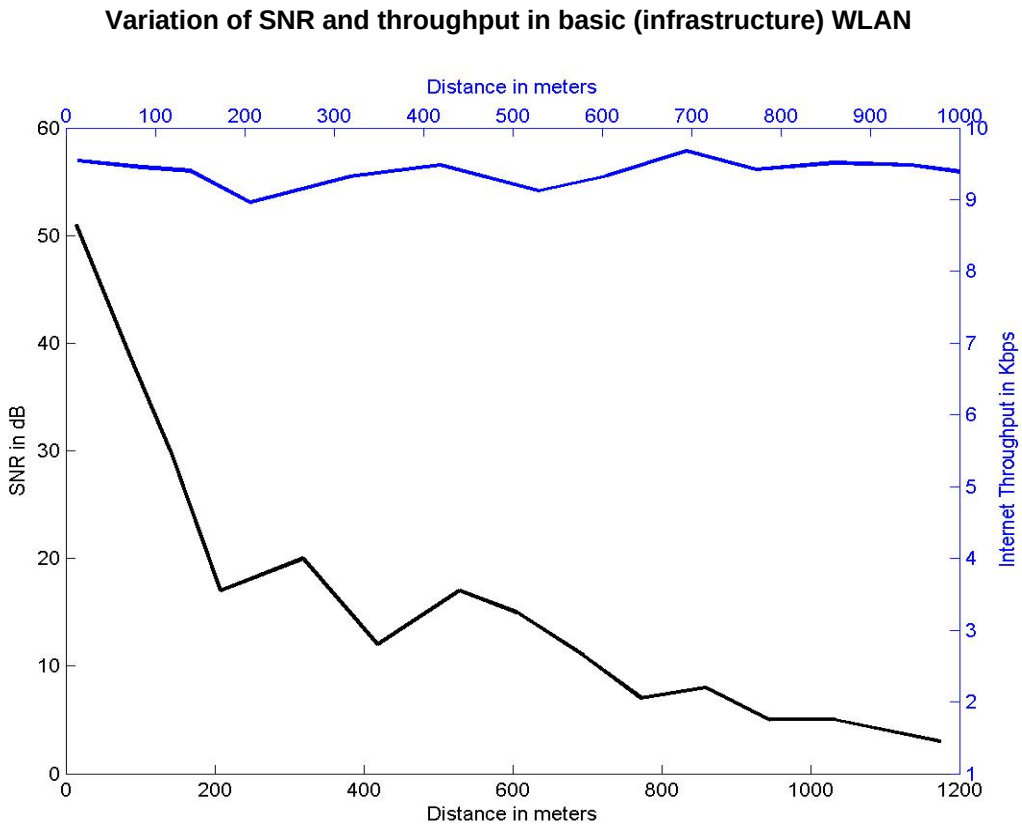


Mobile Vehicle



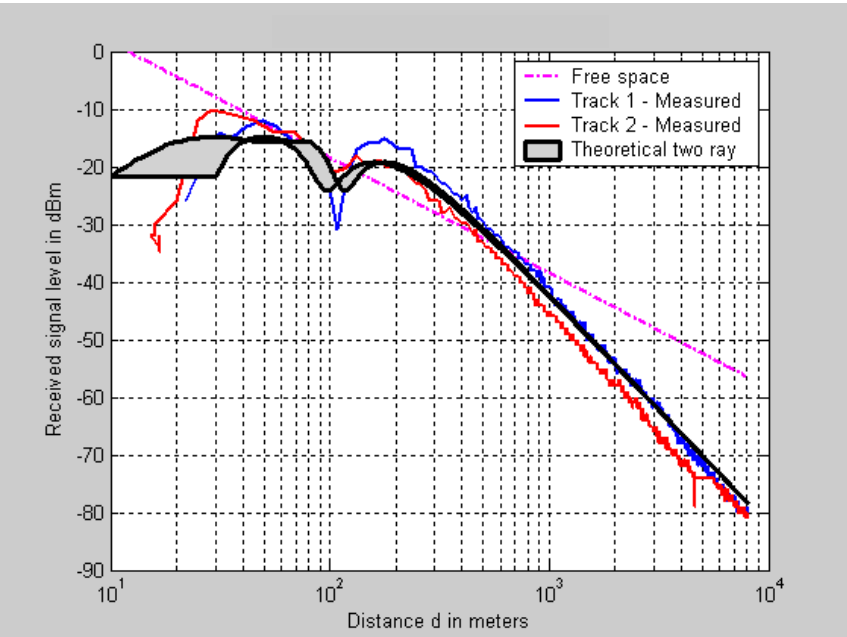
WI-FI system Results – Basic WLAN

- Infrastructure LAN
- Wireless clients with in the camp access the Iridium system
- Variation of SNR with distance
- Internet throughput does not vary with SNR



WI-FI system Results – Extended LAN

Variation of RSS with distance
Base antenna height=3m and mobile antenna height=1.4m GPS error =10m



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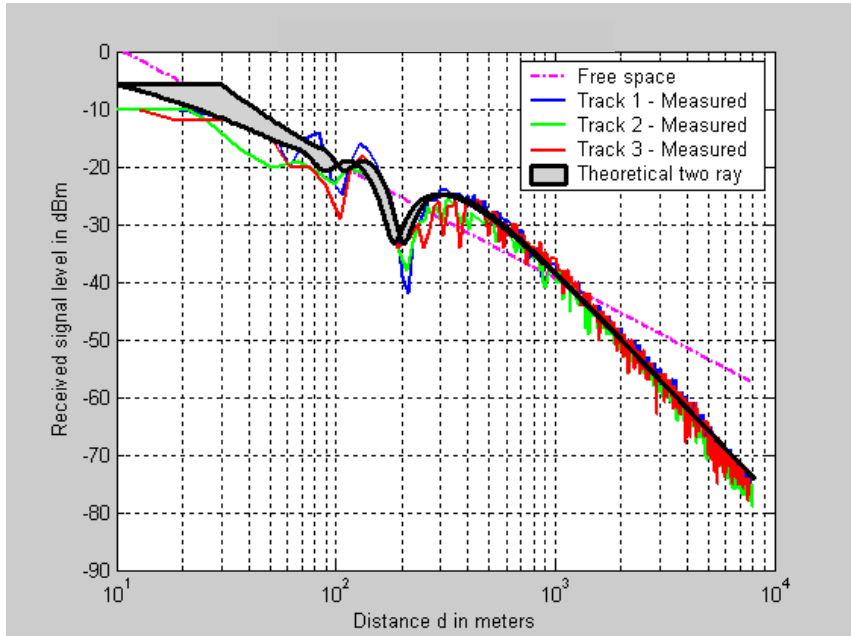
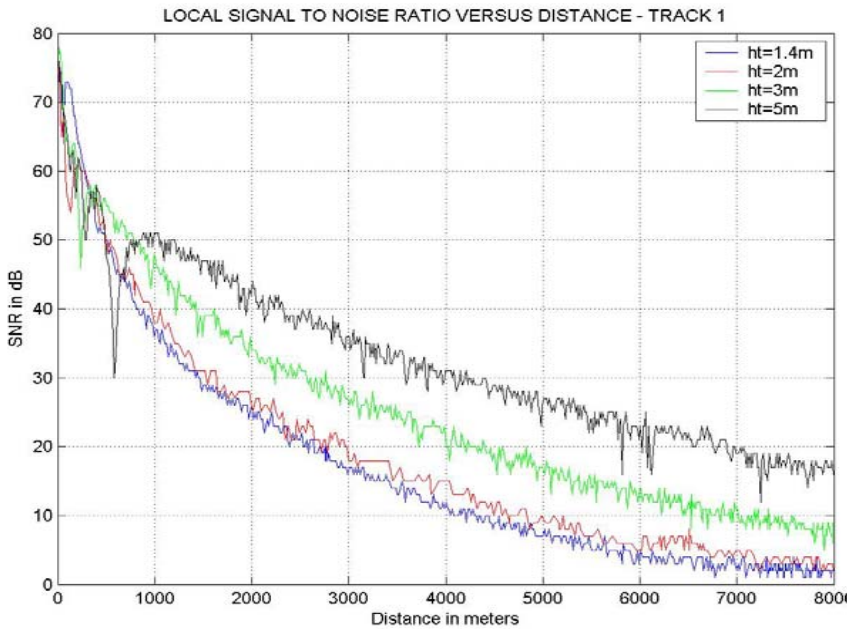


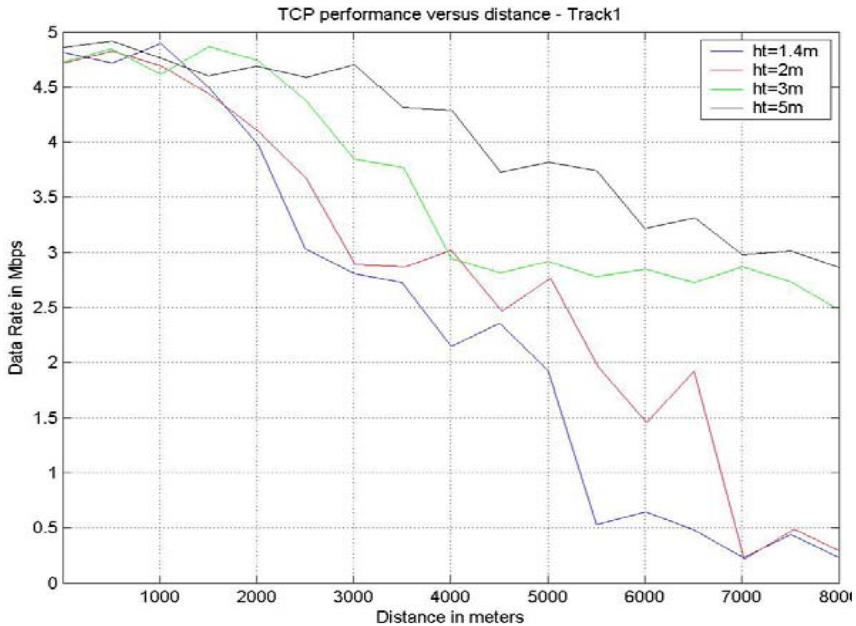
- Measurements are carried out using a fixed base station and a mobile client (peer-to-peer)
- Received signal strength variation matches very well with the theoretical two-ray propagation model
- The effects of using a multi-element antenna is accounted for in the theoretical prediction

WI-FI system Results – Extended LAN

Variation of signal to noise ratio along track 1 for equal antenna heights of 1.4, 2, 3 and 5 at the base station and mobile vehicle



Corresponding TCP throughput measured every 0.5 Km



- Throughput varies from 4.9 – 0.2 Mbps depending on the SNR
- Throughput does not decrease monotonically with packet errors inherent in a 802.11b link.

Applications - Wireless Internet

- Data telemetry
- Wireless Internet/email access
- Download critical software on field (up to 7.2 MB)
- Obtain expert help while on the field
- Collaborate field experiments with mainland research facilities
- Public outreach – video clips, daily reports, etc.

- General camp purpose: sending drawings to order spares for a broken caterpillar, excel spreadsheet for food order, general press releases downloading weather reports for planning C-130 landings

Conclusions

- Multi-channel Iridium communication could be used to reliable provide data and Internet access to Polar Regions.
- This system is easily scalable, lightweight, readily available and has round the clock, pole-to-pole coverage.
- The developed link management software ensures fully autonomous and reliable operation
- The Iridium system can be integrated with reliable long range 802.11b wireless to provide connectivity for distances up to 8 Km
- The validity of two-ray propagation model over flat ice sheets in Polar Regions is proved
- The system provided for the first time, wireless data and Internet access to NGRIP camp in Greenland.

Questions ? Comments?

THANK YOU

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