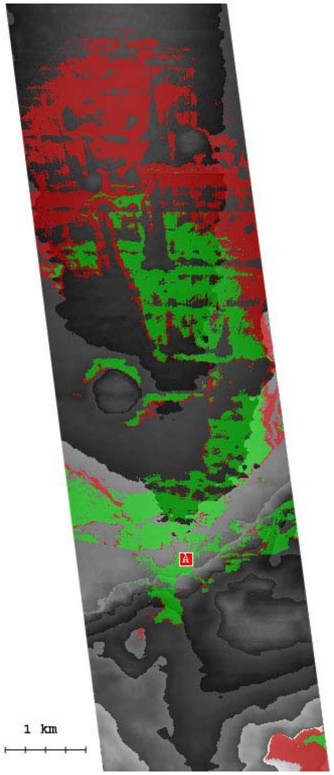

Utilization of Commercial Wireless Networking Technology in Simulated Martian Environments

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Topics

- Project Motivation & Goals
- Modeling the RF Environment on Mars
- Protocol Simulation Suite
- Performance Evaluation of the 802.11a Standard
- Performance Evaluation of the 802.11b Standard
- Conclusions & Recommendations

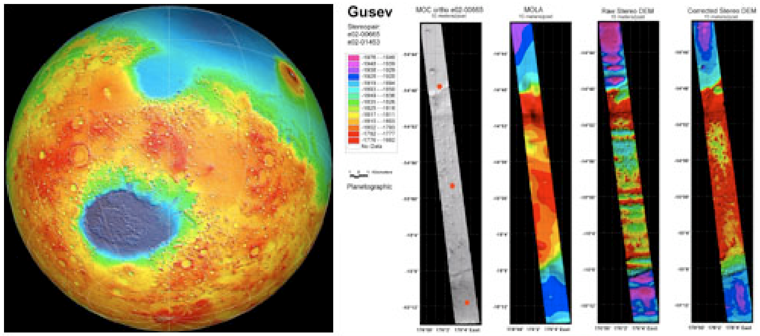
Project Motivation & Goals

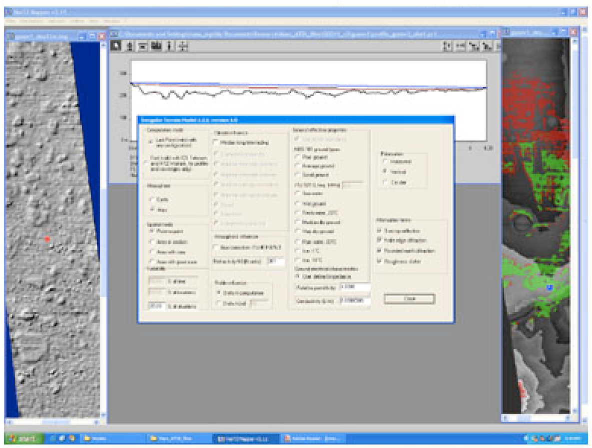
- NASA plans for future planetary exploration include the use of wireless networks in sensor web and planetary rover applications
- Research questions:
  - What are the limitations (power, range, data rate) of commercial wireless network technologies (designed for indoor use) in such a planetary application?
  - Is the outdoor multipath so strong as to prevent useful operation?
  - Is there an advantage to using IEEE 802.11a vs. 802.11b? If so, is a general advantage or only under specific terrain conditions?
  - What is the network performance as a function of the number of nodes?

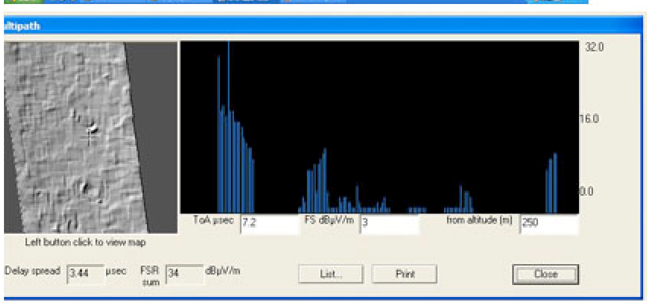
Project Motivation & Goals

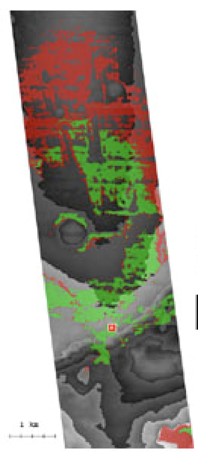
- Simulate the RF environment of proposed landing sites on Mars using digital elevation models (DEMs) from Mars Global Surveyor and RF planning/ propagation software tools; use current primary landing sites at *Gusev Crater* and *Meridiani Planum* as test subject areas for study and modeling
- Understand limitations such as power, range, data rate, BER of COTS wireless networking technology when utilized on planetary surface
- Propose modifications to COTS wireless technology that would enable reliable networking of nodes on a planetary surface

Modeling the RF Environment on Mars









MOLA, MOC-NA
Data from MGS

↓

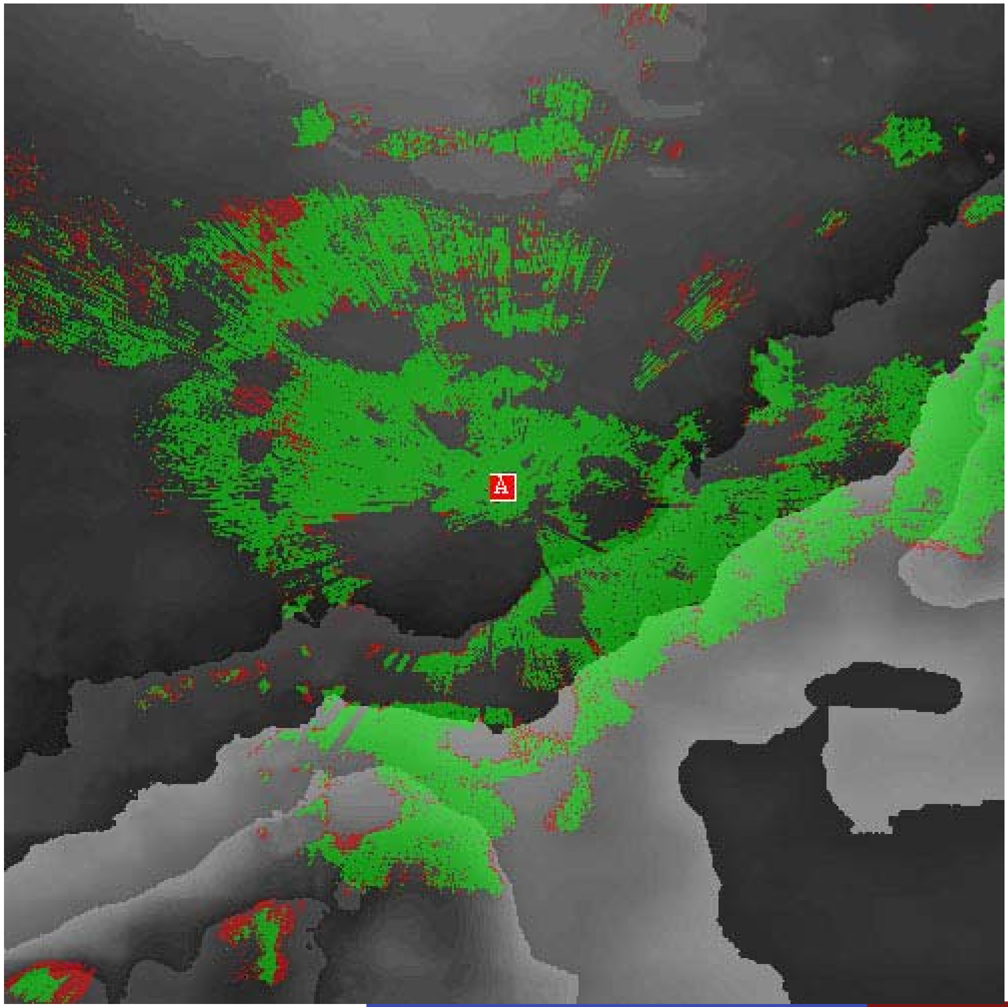
RF Simulation
Software

↓

RF Channel Model:
Power Delay Profile
& RF Coverage

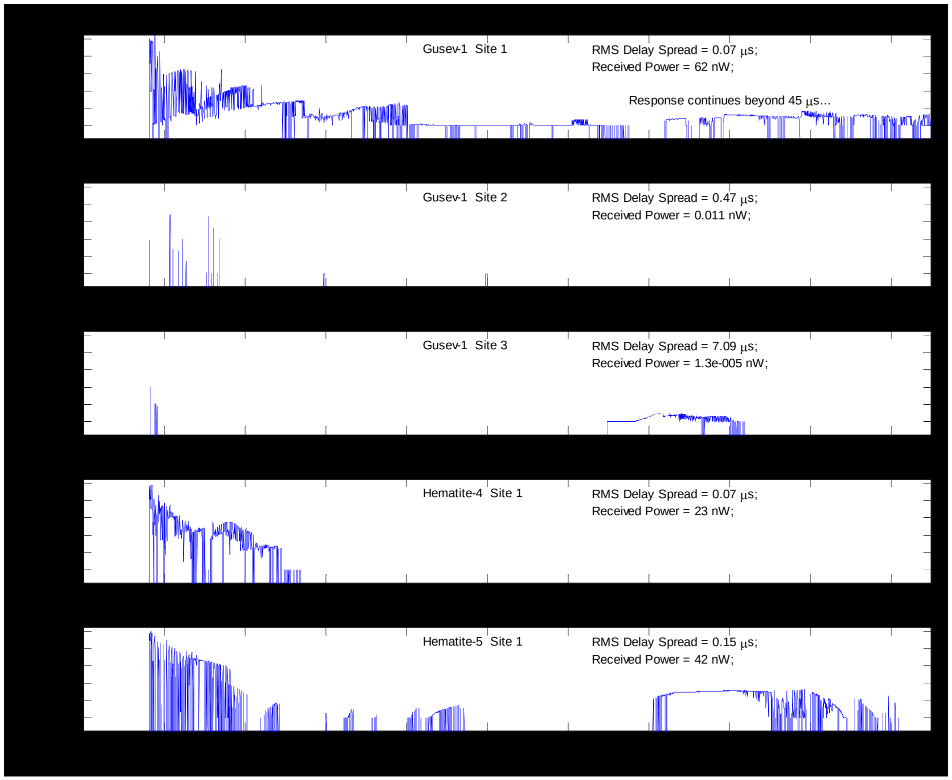
- ATDI's *HerTZ Mapper* and *ICS Telecom*
  - Software for radio network planning, spectrum management, and radio coverage analysis
  - RF models take into account environmental data and system parameters (code parameters modified for Mars)

Modeling the RF Environment on Mars



- RF coverage patterns for Gusev1, Site 1
  - Green denotes -84dBm
  - Red denotes -93dBm
- *Site Coverage* = 32.42% (without clutter) 19.55% (with clutter)
- *Maximum Coverage Distance*, d_{max} = 1137m (without clutter) 1185m (with clutter)

Modeling the RF Environment on Mars



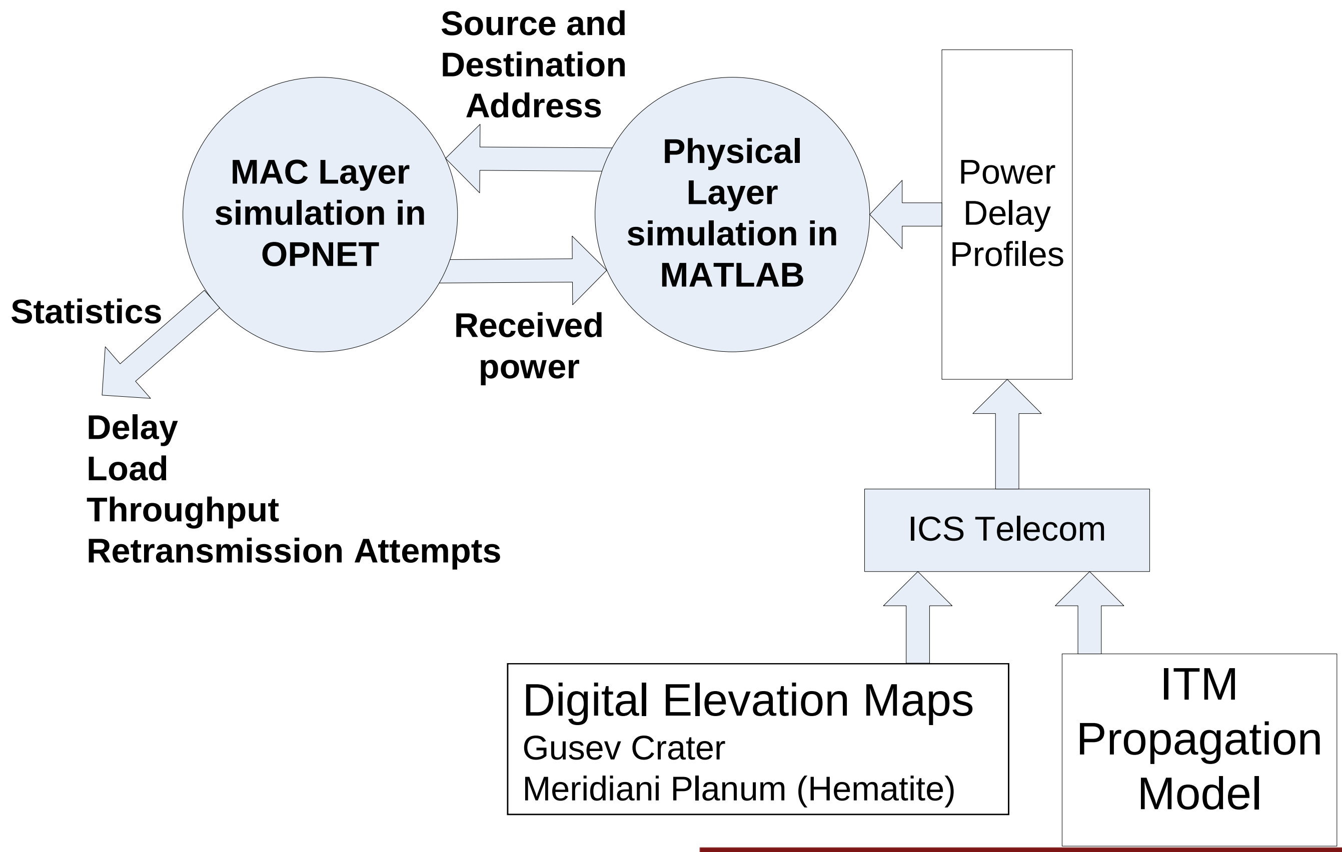
- In addition to the power studies, the simulation software was used to generate Power Delay Profiles (PDF) for various locations.
- Simulations were validated against measurements made locally.

Protocol Simulation Suite

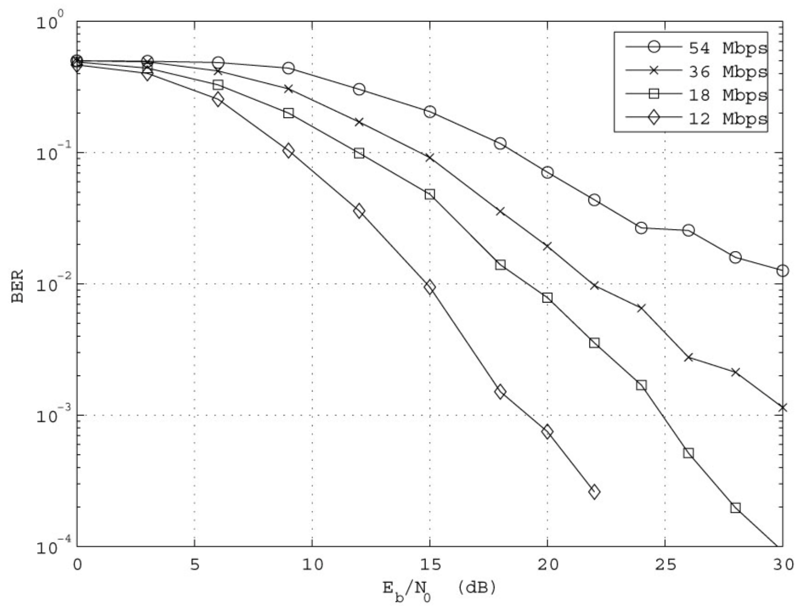
- The PDP's generated form the basis for the IEEE 802.11 a/b simulation studies to determine the performance of the physical and medium access layers in this environment.
- Used the following tools for performance simulations:
  - mWLAN toolbox for MATLAB to simulate the physical layer performance for the IEEE 802.x protocols
  - OPNET run as a co-simulation for the networking performance simulation; calls mWLAN for physical layer performance

MAC Layer Simulation Methodology

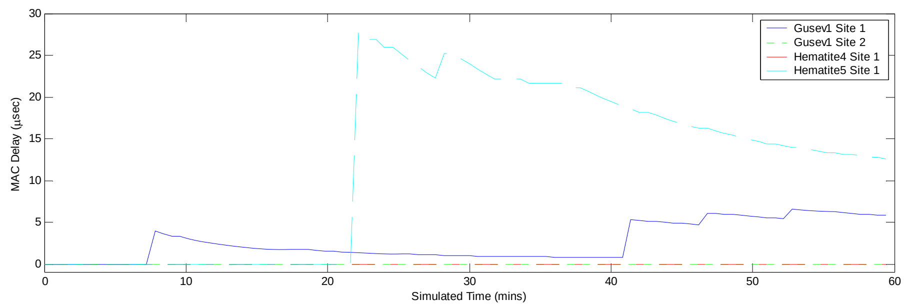
OPNET-MATLAB Co-Simulation

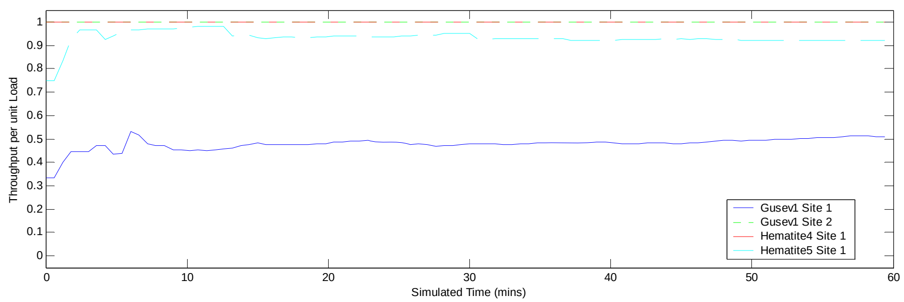


Performance Evaluation of the 802.11a Standard



BER for Gusev 1, Site 1





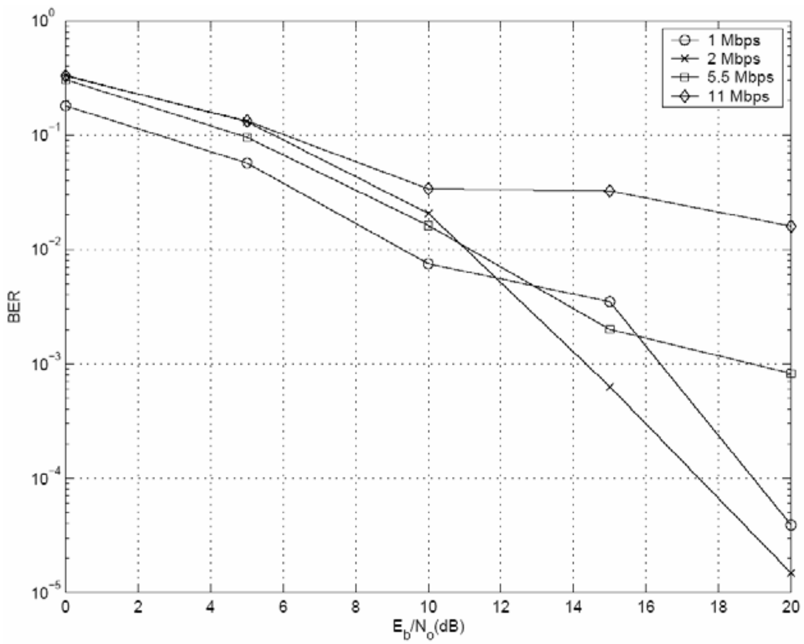
Network MAC delay and relative throughput at different sites.

Performance Evaluation of the 802.11a Standard

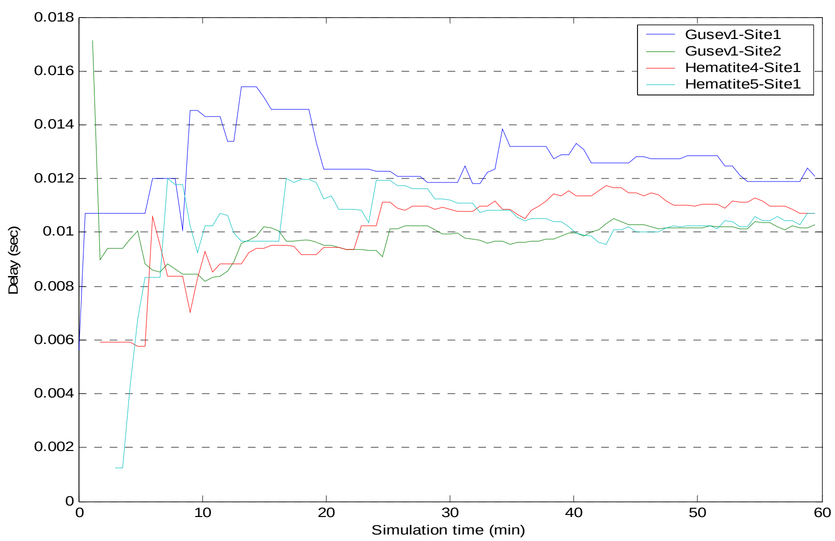
- **Physical Layer Results:**
  - Error Rates are “Not Bad” for Dist < 500 m
  - PER < 0.1 is Easy for MAC to Handle
    - Multipath Dominates Noise, for PTX > 1 mW
  - Antenna Height Helps, for Very Low Power
    - Might Hurt, for Higher Power
  - Behavior Very Location Specific
    - Hills & Valleys

- **Networking Results:**
  - Pretty Good Overall
  - Gusev1 Site 1 is Mediocre
    - Opposite of PHY Trend
  - At Hematite4:
    - 3,4,5 Nodes – All Okay
    - Tx Pwr ≥ 100 µW – All Okay
    - 100 vs 1024 Bytes/Pkt – Both Okay
    - More Traffic → Delay Only

Performance Evaluation of the 802.11b Standard



BER for Gusev 1, Site 1



Network MAC delay at different sites.

Performance Evaluation of the 802.11a Standard

- **Physical Layer Results:**
  - Increase in antenna height does not improve performance significantly for 802.11b within 0.5 m to 2 m.
  - RAKE receiver improves performance significantly for 802.11b.

- **Networking Results:**
  - Large MAC layer delay due to significant number of retransmissions. Throughput per unit load is severely limited by multipath.
  - Increasing number of nodes from 3 to 5 does not significantly affect delay and slightly decreases throughput per unit load for low packet arrival rates.
  - Large packet sizes increase delay and decrease throughput per unit load. However, there is less energy per successful bit.
  - Increase in power from 1 mW to 1 W does not improve MAC layer performance significantly.

Conclusions & Recommendations

- The use of commercial link planning software can be successfully used to model rover-type performance on the surface; validation is necessary to make sure that the parameters are set properly.
- The simulations showed two definite regions: a power-limited region and a multipath-limited region.
  - As expected, increasing power in the power-limited region helps until the multipath-limited region is reached.
- Simulations showed a great deal of variation from site to site as the local topology changed. Location needs to be accounted for in route planning.

Conclusions & Recommendations

- *IEEE 802.11a* has good Physical Layer performance up to a few hundred meters; lower data rate shows better BER than high data rate
- *IEEE 802.11b* was more sensitive to the multipath effects
  - a RAKE receiver improved performance
- *IEEE 802.11a* had better MAC performance than *802.11b*
  - Packet size, data rates, retry rates, and other parameters can be selected to tweak results.

Conclusions & Recommendations

- Recommendations
  - Re-clock *IEEE 802.11a* for long multipath management (extends guard interval at the cost of halving the data rate)
  - Investigate *IEEE 802.11g* (lower carrier frequency alone can give improvement)
  - Look into coming standards such as *IEEE 802.11n* and *IEEE 802.16* that are being designed for mutipath and/or outdoor links.