IAF SPACE COMMUNICATIONS AND NAVIGATION SYMPOSIUM (B2)
Advances in Space-based Communication Systems and Services, Part 3 (4)

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COMMUNICATIONS ARCHITECTURE FOR MARTIAN SURFACE EXPLORATION WITH A SWARM OF WIND-DRIVEN ROVERS

Abstract

This decade has seen growing interest in Mars exploration. Advances in distributed systems, miniaturization and commoditization of space electronics and innovations in communications permit us to rethink the current paradigm of relying on a few heavy, slow and expensive high-tech rovers for Mars surface exploration. In this work, we address the demanding communication needs for a mission that deploys a swarm of uncontrolled wind-driven exploration rovers onto the Martian surface.

The concept for these lightweight, autonomous, ellipsoid "Tumbleweed" rovers — named after the desert plant — is not new, it has been studied and validated by NASA researchers decades ago. Recently, a new plan to turn the Tumbleweed mission into reality has been proposed to the ESA open space innovation platform (OSIP). The idea is to launch approximately 90 Tumbleweeds in one transfer vehicle and release them on the Martian surface to survey the northern hemisphere of Mars over a mission duration of 3 months. This is adressed in the abstract number 72458 submitted by J. Rothenbuchner.

Challenges regarding communications are significant for this mission. The swarm of rovers generates enormous volumes of data; many rovers need to be served simultaneously and the tumbling motion on the Martian surface constitutes unprecedented challenges in terms of antenna pointing for planetary exploration rovers.

We present a trade-off analysis between direct down to Earth communication and relayed communication using satellites orbiting Mars culminating in a baseline communication architecture for the Tumbleweed mission. For this purpose we model the kinematics of the Tumbleweed rovers and relay satellites w.r.t Earth. A numerical simulation of all potential communication links over the full mission duration is conducted. The analysis shows that direct communication to Earth is infeasible due to the rolling motion of the rover. The relayed communication scenario is selected because it does not require a directional antenna on the Tumbleweed rovers. Therefore, we propose a constellation of three relay satellites in a circular, Earth-facing orbital plane around Mars that communicates with the Tumbleweed rovers using the UHF frequency band. Commercial ground stations in Ka-band are used for the relay-ground link. The proposed communications architecture is estimated to achieve a raw data throughput of >84Mbit per Tumbleweed rover per Sol, which is sufficient to fulfill the mission requirements.