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Wireless Sensor Networks – A potential tool to probe for water on Moon

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Abstract

A Wireless Sensor Network for in situ probing of lunar water/ice is proposed. The mission scenario in single and multi-tier architectures for probing water in a permanently shadowed region of the Moon and different scenarios of exploration are discussed. The ideas presented in the paper are a positive assertion of feasibility for the sensor node hardware, given current levels of technological advancements.

Keywords: Moon; Planetary exploration; Water; Wireless Sensor Networks

1. Introduction

The possibility of the presence of water ice deposits in the polar regions of the Moon has drawn a lot of attention in the recent past and continues to be of great interest. The debate of water on the Moon is long continuing since Watson et al. (1961) gave the hypothesis of the existence of lunar ice in cold traps. Later, Arnold (1979) investigated the stability of trapping mechanisms for water ice in polar regions of the Moon. The lunar polar regions contain areas that are permanently shadowed from solar illumination (Bussey et al., 1999; Margot et al., 1999), and act as "cold traps" for volatiles delivered by comets or formed by solar wind interactions with the regolith (Crider and Vondrak, 2000). Observational evidences from the Clementine bistatic radar experiment (Nozette et al., 1996) and the Lunar Prospector neutron spectrometer (Feldman et al., 1998, 2001) were not unambiguous as these signatures cannot definitely be attributed to water/ice. High precision studies of lunar volcanic "green glass" have indicated a significant amount (~700 ppm) of indigenous water on the Moon (Saal et al., 2008). Recent lunar orbiter missions, Chandrayaan-I and Lunar Reconnaissance Orbiter (LRO), have provided a definitive evidence for the presence of various forms of water (regolith bound H_2O, hydrogenated minerals and water–ice) on the Moon. The Moon Mineralogy Mapper (M^3) onboard Chandrayaan-I has discovered a surficial mobile molecular layer of OH/H_2O by detecting a characteristic absorption feature around 3.0 μm, which is attributed to OH/H_2O bearing minerals (Pieters et al., 2009). M^3 observations were also supported by observations from Cassini (Clark, 2009) and Deep Impact (Sunshine et al., 2009) missions. Statistical and morphological analysis of polarimetric radar data acquired with Mini-SAR (Spudis et al., 2010) onboard Chandrayaan-I showed the possible presence of water–ice in permanently shadowed craters near the north pole of the Moon. Finally, observations from the LCROSS (Lunar CRater Observation and Sensing Satellite) impact in Cabeus crater near the lunar south pole has provided a confirmative evidence for the presence of water on the Moon in the form of water–ice (Colaprete et al., 2010; Schultz et al., 2010). LCROSS observations showed strong and convincing features of hydroxyl, mineral bound H_2O and water–ice. Although orbiter mission observations gave a clear indication of lunar water, in-situ investigations are necessary for

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further confirming the occurrence of water on the Moon to understand its nature, distribution and the process of formation/accumulation. Water (ice or H_2O in any form) is an important resource on the Moon. If it indeed exists in larger amounts, it would greatly support human expansion to space. Accessible deposits of water on the Moon would profoundly affect the economics and viability of a human presence on the Moon. For a permanent or reusable base a local supply would be invaluable both for human needs in the form of water and oxygen, and for production of rocket fuel. According to the current global mean lunar temperatures (Paige et al., 2010), the sunlit (~400 K) and shadowed side (~100 K) of the Moon differ by ~300 K, resulting in continuous migration of volatiles (like H_2O) from illuminated to non-illuminated regions. However, because of the slight axial tilt (~1.5°) of the Moon's spin axis to the ecliptic plane, some deep craters near the poles never receive light from the Sun and are thus in permanent shadow (e.g. the Shackleton crater). The temperatures in these cold traps can be as low as 29 K (Paige et al., 2010). Water molecules that get trapped in these craters could stay there for long periods of time and act as reservoirs for substantial deposits of lunar water. Based on recent results from the Kaguya laser altimeter, the permanently shadowed regions (PSRs) on the Moon have been estimated to be nearly 1236 and 4466 km^2 in the north and south polar regions respectively, while these values beyond 87.5° are estimated to be 844 and 2751 km^2 at north and south poles of the Moon (Noda et al., 2008). In this paper, we propose various options to apply a Wireless Sensor Network for in-situ detection of water on the Moon.

2. Wireless Sensor Networks

Wireless Sensor Networks (WSN) are an upcoming technology (Akyildiz et al., 2002; Cayirci et al., 2003; Raghavendra et al., 2004; Znati et al., 2003) and will become potentially powerful tool for space and planetary exploration missions because of their unique capability of deployment and autonomous data gathering tasks in an unfriendly and unattended environment. Besides they can overcome the limitations of Landers and Rovers on planetary surfaces for carrying out in-situ measurements. Although WSN have not been used for space and planetary platforms till now, suggestions have been made for using WSN for upcoming space and planetary missions (Dubois et al., 2009; Gaura and Newman, 2006). As shown in Fig. 1, Wireless Sensor Networks consist of a large number of tiny, battery-powered computing devices often called as NODES that are scattered through a physical environment to form an adhoc network with self organizing capability (Akyildiz and Wang, 2005; Akkaya and Younis, 2005; Chong and Kumar, 2003; Deshpande et al., 2004; Durga Prasad and Murty, 2009; Egea-Lopez et al., 2006). Autonomously and wirelessly, each node in this adhoc network collects data with the help of its onboard sensors and relays it to the neighbouring nodes and then to a specified destination (base station), where it is processed. Such a data gathered from all the nodes gives a high-resolution picture of the surrounding phenomenon in real time. The position of the sensor nodes need not be wangled allowing random deployment in an inaccessible terrain.

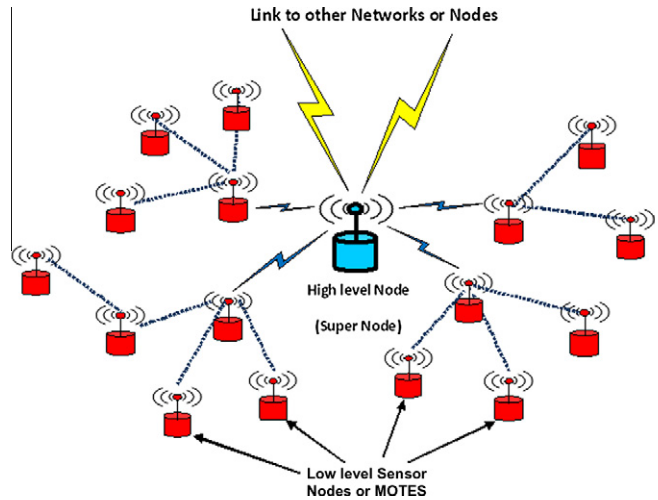

Fig. 1. Wireless Sensor Network.

WSN, in principle, offer an efficient way to probe one or several geophysical, geochemical and environmental parameters on a planetary surface, depending on the sensors integrated on the node. Here we propose a water probing sensor network for the Moon using a number of wireless sensor nodes, to collect data simultaneously from a large area of a permanently shadowed region (PSR) which are likely to harbor large deposits of water ice. A laboratory prototype of such a network in a lunar analogous environment is being designed using commercially available sensor nodes and sensors. Two different platforms have been considered for designing such a sensor node. Dielectric or Infrared technique has been suggested for water sensing. In this paper, we focus mainly on the implementation of the WSN technique for in situ detection of water in a permanently shadowed crater and the design of a miniaturized sensor suitable for such an experiment has been described elsewhere (Durga Prasad and Murty, 2010).

3. Need of Wireless Sensor Network for lunar exploration

A large amount of water on the Moon is expected in the cold and dark bottom of impact craters near the poles. Detecting water ice in such a location is extremely difficult, especially if the ice is covered by, or imbedded in the lunar soil. A Rover or Lander can be deployed in such regions for carrying out in-situ measurements, but the data collected will be limited to a specific number of data points and one location at a time. Further, the mobility and operation of a Lander or a Rover in PSR is extremely challenging. The overall risk of operating a Rover or Lander in a