Finding water on Mars using neutral atoms

Perseverance landed on Mars on last 18th of February inside of the Jezero Crater. With a diameter of over 40km, the crater is believed to have been filled with water 3.5 billion years ago. Conceivably, microbial life could have lived in Jezero lake during the time it was wet. Also, it is possible that water still exists under the surface: recent data from the Mars Global Surveyor suggest that liquid water may exist just below the surface in rare places. Finding Martian sources of water is of capital importance to prepare for the human exploration of Mars. Rovers, drones and other robots sent to Mars have been conscientiously sensing and searching for such sources of water for years now. A noble but difficult task: Curiosity has only covered a 24km thin line in two years… a bit like finding a needle in a haystack!

Mobile Ad Hoc NETworks (MANETs)

Looking at the size of this daunting task, it might be more efficient to send a fleet of autonomous nano-sensors that could work collectively to explore areas of Jezero. Ultra-light weighted, each mobile sensor is equipped with a power source, a short connection range and a small amount of memory. At any time, the positions of the sensors define a graph, where an edge between two nodes represents a communication link (Fig.1). Each node can activate a "transmitter" feature to relay information to its closest neighbors. By transmitting information between them, the sensors can move collectively to areas of interest like a bird swarm.

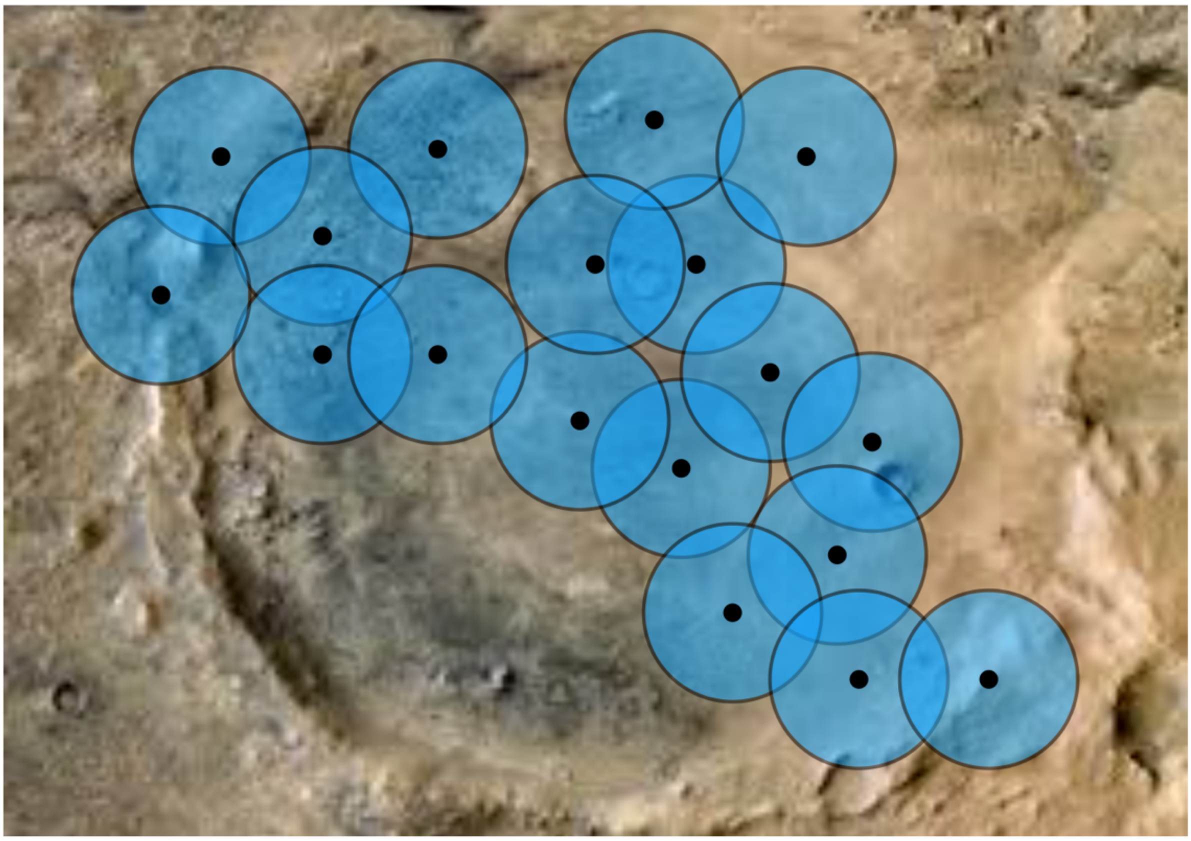

Figure 1: A mobile fleet of autonomous sensors hovers over Jezero in the hope of detecting underground water.

The need for a virtual backbone: Connected Dominant Set

Because of the short connection range, having all nodes in transmitter mode guarantees global communication. However, activating the transmitter feature drains the battery of the nano-sensors and many redundant nodes will spread the same information.

In order to preserve the precious lifetime of the sensor population, an efficient method is to define a *virtual backbone* for each graph topology. A virtual backbone is a subset of the nodes that are the only ones used for routing, *i.e.* put in transmitter mode, while the others save energy by only doing the sensing task. Nodes in the virtual backbone can communicate with each other and can relay information to any other node of the graph.

Find a Connected Dominant Set by finding the UD-MIS

The virtual backbone corresponds to the Connected Dominant Set (CDS) of the graph, which is NP-hard to find. A dominating set (DS) D of a graph G=(V,E) is a subset of V such that each node in V\D is adjacent to at least one node in D. A Connected Dominant Set C of a graph G is a dominating set of G, and such that the subgraph G[C] is connected.

Every single time the sensors move, it is of crucial importance to find a CDS, and so a NP-hard task has to be solved repetitively within a constrained time budget.

In this challenge, you will see how the CDS of a graph can be efficiently found using the platform of atoms of Pasqal, which exploits the laws of quantum physics. Helping humans find water on Mars by using an ensemble of atoms…