



Metaverse in InterPlanet Internet: a  
Time-Dependent Platform for the  
Robotic-mediated Implementation of Complex  
Applications in Space

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# **Metaverse in InterPlanet Internet: A Time-Dependent Platform for the Robotic-mediated Implementation of Complex Applications in Space**

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## **ABSTRACT**

The interplanet internet is a conceived computer network in space, consisting of a set of network nodes that can communicate with each other. These nodes are the planet's orbiters (satellites) and landers (e.g. robots, autonomous machines, etc.) and the earth ground stations, and the data can be routed through Earth's internal internet. As resource depletion on Earth becomes real, the idea of extracting valuable elements from asteroids or using space-based resources to build space habitats becomes more attractive, one of the key technologies for harvesting resources is robotic space mining( minerals, metals, etc.,) or robotic building of space settlement. The metaverse is essentially a simulated digital environment mimicking the real world. The metaverse would be something very similar to real world planetary activities where users( space colonies or internet users on Earth) interact with overlaying objects represented by robots, drones, etc. for real-world planetary activities like space mining, building space settlements, etc. in a completely virtual manner. In this paper, we use information about different time steps as represented by the observation matrix for the presence of the robots in a planetary environment. The observation matrix is a 3-dimensional matrix with time as a third dimension and it encodes the robots presence at different time steps . We then pass this matrix through a 3-dimensional convolution network for deriving additional system information mimicking the real world execution by robots while being able to connect with others. Here, we present time dependent encoding model and AI concepts to achieve very reliable tracking of the robots and the environment for creating a simulated realistic world for successful execution in a distant planet by exhibiting a

realistic similar to human behaviour by robots. The results of the study simulated on existing internet here on Earth show that the real individual behaviour on a distant planet can be achieved provided the interplanet internet is available as pathway communication.. Therefore, connected metaverse with multiple set-ups of virtual spaces with different time-dependent encoded layers could be of reality even in interplanet environment.

## **INTRODUCTION**

Inter-planetary exploration, be it Lunar habitation, asteroid mining, Mars colonization or planetary science/mapping missions of the solar system, will increase demands for inter-planetary communications. The movement of people and material throughout the solar system will create the economic necessity for an information highway to move data throughout the solar system in support of inter-planetary exploration and exploitation. The communication capabilities of this interplanet information highway need to be designed to offer; 1) continuous data, 2) reliable communications, 3) high bandwidth and 4) accommodate data, voice and video.

The interplanetary Internet is a conceived computer network in space, consisting of a set of network nodes that can communicate with each other. These nodes are the planet's orbiters (satellites) and landers (e.g., robots), and the earth ground stations. For example, the orbiters collect the scientific data from the Landers on Mars through near-Mars communication links, transmit the data to Earth through direct links from the Mars orbiters to the Earth ground stations, and finally the data can be routed through Earth's internal internet. Interplanetary communication is greatly delayed by interplanetary distances, so a new set of protocols and technology that are tolerant to large delays and errors are required. The interplanetary Internet is a store and forward network of internets that is often disconnected, has a wireless backbone fraught with error-prone links and delays ranging from tens of minutes to even hours, even when there is a connection. In the core implementation of Interplanetary Internet, satellites orbiting a planet communicate to other planet's satellites. Simultaneously, these planets revolve around the Sun with long distances, and thus many challenges face the communications. The reasons and the resultant challenges are: The interplanetary communication is greatly delayed due to the interplanet distances and the motion of the planets. The interplanetary communication also

suspends due to the solar conjunction, when the sun's radiation hinders the direct communication between the planets. As such, the communication characterizes lossy links and intermittent link connectivity.

The graph of participating nodes in a specific planet to a specific planet communication, keeps changing over time, due to the constant motion. The routes of the planet-to-planet communication are planned and scheduled rather than being fluctuating. The Interplanetary Internet design must address these challenges to operate successfully and achieve good communication with other planets.

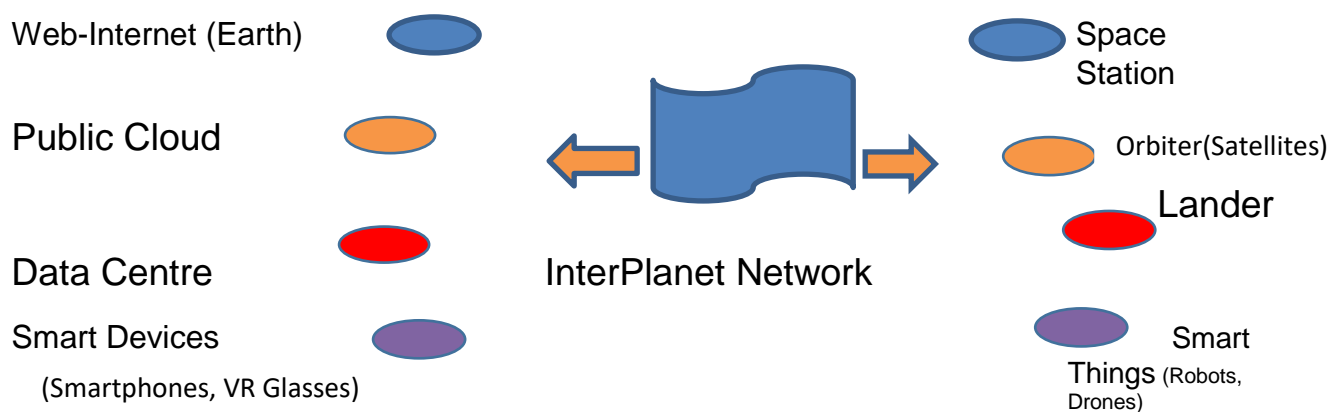
## NETWORK ARCHITECTURE

A **Computer Network Architecture** is a design in which all computers in a computer network are organized. An architecture defines how the computers should get connected to get the maximum advantages of a computer network such as better response time, security, scalability, etc.

Network architecture refers to the way network devices and services are structured to serve the connectivity needs of client devices.

- Network devices typically include switches and routers.
- Types of services include DHCP and DNS.
- Client devices comprise end-user devices, servers, and smart things.

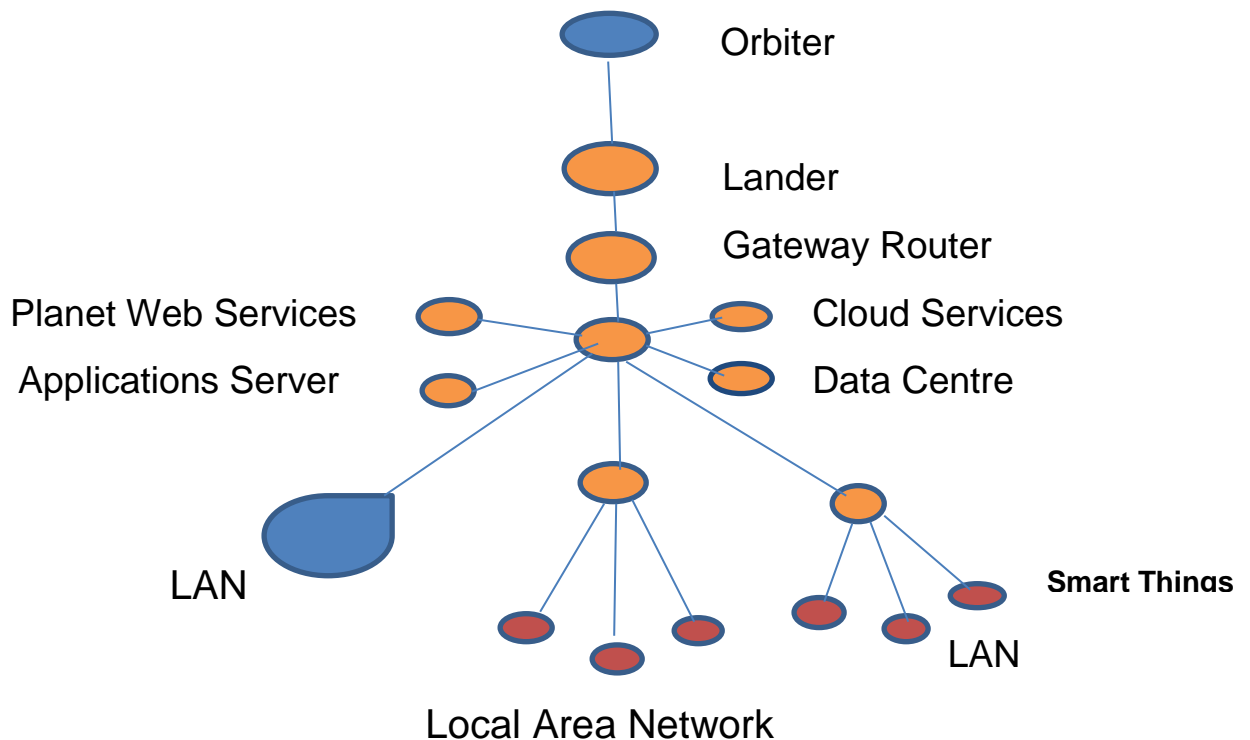
The network architecture for the planet Mars or the Moon is as shown in below figure:-



Computer networks are built to serve the needs of certain functionality and also their clients. Described below are three types of planetary networks:

- Access networks, for campuses and local areas, are built to bring machines and things onboard, such as connecting robots, drones, etc. within a location.
- Networks for data center connect servers that host data and applications and make them available to smart devices.
- Wide-area networks (WANs) connect robots and others to applications, sometimes over long distances, such as connecting robots to cloud applications related to space mining operations.

We give below the architecture of network on the planet Mars or the Earth's Moon is as shown in below figure:-



An Internet is a “network of networks” in which routers move data among a multiplicity of networks with multiple admin. domains.

The main aim of networks is to connect remote endpoints with end-to-end principle and network should provide only those services that cannot be provided effectively by endpoints.

Since the networks are predominantly wireless, the fundamental impact of distance due to speed-of-light delays and impact on interactive applications – for both data and control is to be considered. Also power

consumption of wireless links as a function of distance is to be examined.

The interplanetary internet is a conceived networks of nodes and these nodes are space station, planet's orbiters ( satellites ), planet's landers, robots ( drones, autonomous machines, etc. ), earth ground stations and earth's internal internet.

## **METHODOLOGY**

Outer space contains a vast amount of resources that offer virtually unlimited wealth to the humans that can access and use them for commercial purposes. One of the key technologies for harvesting these resources is robotic mining of minerals, metals, etc. The harsh environment and vast distances create challenges that are handled best by robotic machines working in collaboration with human explorers. Humans will visit outposts and mining camps as required for exploration, and scientific research, but a continuous presence is most likely to be provided by robotic mining machines that are remotely controlled by humans either from Earth or from local space habitat.

Future **Moon( or Mars )** bases will likely be constructed using resources mined from the surface of the Moon/Mars. The difficulty of maintaining a human workforce on the Moon( or Mars ) and communications lag with Earth means that mining will need to be conducted using **collaborative robots** with a high degree of autonomy. Therefore, the utility of autonomous collaborative robotics( with thousands of robots in operation ) towards addressing several major challenges in autonomous mining in the lunar( Martian ) environment with lack of satellite communication systems, navigation in hazardous terrain, and delicate robot interactions to achieve effective collaboration between robots and long-lasting operation.

### **Collaborative Robotics**

Robots can be shaped to perform specific tasks. Robots have been designed and shaped in such a way that they can walk, swim, push pellets, carry payloads, carry shoveling and work together in a group to aggregate debris scattered along the surface into neat piles or possibly, to build a space settlement. They can survive for long-time without recharge and heal themselves after any damage/confusion. The shape of a robot's body, and its distribution of legs and structure are

automatically designed in simulation to perform a specific task, using a process of trial and error.

Robots were able to move on their own. And using artificial intelligence, these robots can be programmed as specific executor of an assigned task for a number of situations and also using artificial intelligence to figure out the best shape for the Robots to perform in group on a more consistent basis to have better control over performance of assigned work.

Using a computational model that simulates the nature of work and everything of the Robot Capability, the process yields the robotic shape best suited to ensure the shape of the actual Robots into more efficient form suitable to a particular situation/task and accordingly enables robots to gather together in their environment forming them into groups with the same capability.

The methodology is essentially fundamental for getting the space robots as autonomous as possible and the aim is to represent surroundings and their markings from robot in space. Therefore, we use feature extraction from the environment to update the position of the robot. Landmarks are the features that can easily be observed and distinguished from the environment and these are used to localize the robot.

The methodology primarily consists of following parts:-

1. Selecting and deciding on the landmarks (Materials, location, etc.).
2. Extracting landmarks from input of robot sensors/cameras at each time step.
3. Based on time step, get the current position of the robot on the basis of landmark data.
4. Carryout landmark data association with the location of the robot by matching with the landmarks data in the database.
5. Measuring the outcome with optimization steps after integrating the real world elements with the pre-fed data.

## **ARCHITECTURE**

### ***1. Augmented Reality***

The word 'augmented' means to add. Augmented reality uses different tools to make the real and existing environment better and provides an improved version of reality.

As Augmented Reality (AR) technologies improve, we are starting to see use cases and these include product visualization. There are AR apps that allow a customer to place virtual furniture in their house before buying and it is also a powerful tool for marketing as it allows users to try products before buying.

At its core, AR is driven by advanced computer vision algorithms that compares visual features between camera frames in order to map and track the environment. But we can do more. By layering machine learning systems on top of the core AR tech, the range of possible use cases can be expanded greatly.

Augmented Reality(AR ) can be defined as a system that incorporates three basic features: **a combination of real and virtual worlds, real-time interaction, and accurate 3D registration of virtual and real objects**

## ***2. Camera Representation***

A camera is a device that converts the 3D world into a 2D image. A camera plays a very important role in capturing three-dimensional images and storing them in two-dimensional images. And the following equation can represent the camera.

$$x=PX$$

Here x denotes 2-D image point, P denotes camera matrix and X denotes 3-D world point.

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} p_1 & p_2 & p_3 & p_4 \\ p_5 & p_6 & p_7 & p_8 \\ p_9 & p_{10} & p_{11} & p_{12} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

The above is vector representation of  $x=PX$  [1].



The camera representation method is frequently used in image processing and is intended to identify the geometric characteristics of the image creation process. This is a vital step to perform in many computer vision applications, especially when metric information on the scene is needed.

### **3. *Metaverse Algorithm***

#### **1. Physical Reality Modelling - required information**

- The goal of the agent/robot
- What the robot sees, Materials & location
- Real Simulation for Task Execution

#### **2. Task Execution ( Simulation )**

- Generating actual materials( how materials arrive at the site)
- Robots arrive in the environment ( speed and goal )
- Task Execution( Simulation Steps ), is updated as the work process progresses in line with the simulation
- Task execution performance, as we have fully functional simulator and to make a realistic system, we would like to see how well it performs and mirrors real world execution( Artificial Intelligence )
- Implementation of Graphical Version of the Task Execution

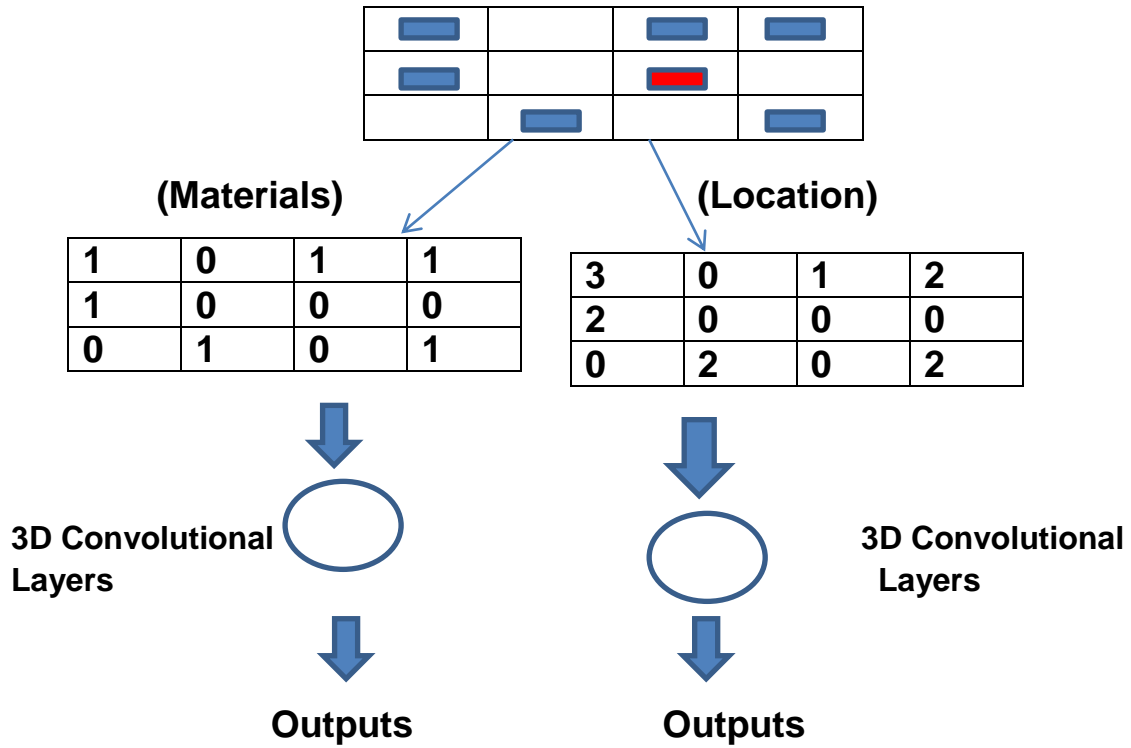
### **Models for Metaverse & Algorithm**

#### **Minimum amount of required information**

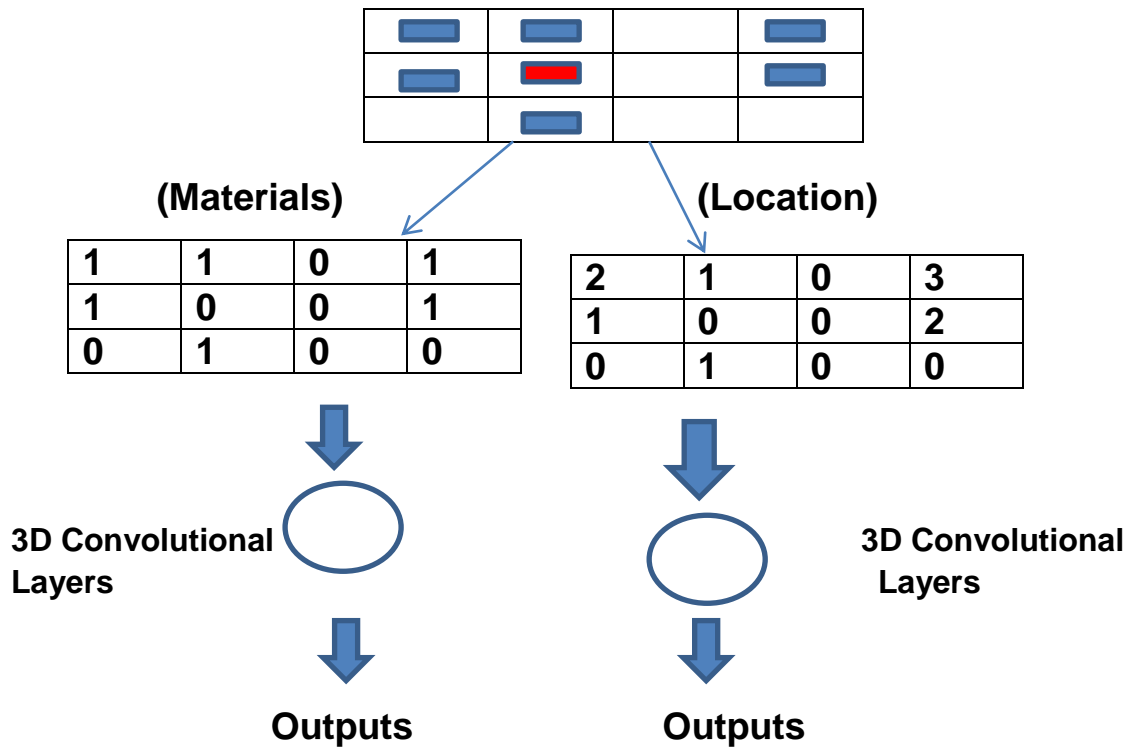
- The current state of the robot/agent and its environment
- The goal of the agent/robot
- What the agent sees, materials & it's location

### **4. *Reddy's Encoding Model***

**A) Agent/Robot Sight at Time Step (t)**



**B) Agent/Robot Sight at Time Step (t + 1)**



**Fig 1. Model encoding of an agent/robot with a goal.**

Our first step is the basic information regarding the robot vision and its location. We define the model with each input as either 0 or 1 and information regarding the field of view of the agent/robot can only be 1 if there is something , or 0 if there is nothing. The agent/robot only knows whether there is a material to be used in some position and its location with respect to materials identified.

We have represented this model as matrix with encoded values with possible values for each of these attributes.

### **5. Algorithm( Metaverse )**

```
For field of view of agent at time step t do  
  (# Encoding observation)  
  If materials in cell x then  
    Initialize matrix  
    (# Matrix initialization)  
    If material in cell x then  
      Mark the location & initialize matrix  
      If material in cell x then  
        Carry task as per simulation process  
        If carried task is as per the goal then  
          Exit  
        Else repeat the task  
        End  
      End  
    End  
  End  
End  
End  
End
```

## **RESULTS**

First, the robot gathers useful information from the environment to track the environment and also the objects tracked are reliably located at time step  $t$ . Based on the observations of the robot, we used 3-dimensional convolutional layers on the inputs at different time steps ( we used only two time steps, however can be extended to more units for the time dimension) representing the robot observations and the same is applied for the two attributes. The output of these CNNs are then used as input to the optimization model for achieving the desired goal and the end result is satisfactory with optimization of the network.

## **CONCLUSION**

The interplanetary computer network in space is a set of computer nodes that can communicate with each other. We proposed a network architecture with planet's orbiters, landers (robots, etc.), as well as the earth ground stations and linked through Earth's internal internet, and consisted of complex information routing through relay satellites to address direct planet-to-planet communication. As we know, the metaverse will be very different from the internet of today due to massive parallelism, three-dimensional (3D) virtual space and multiple real-world spaces like space mining, building space habitats, etc. This paper presents a time dependent observation matrix at different time steps in a planetary environment for layering the presence of robots and tracking the environment that use encoded model and AI mimicking the real world execution by space robots while being able to connect with others. For this 3-dimensional matrix with time as third dimension and AI-convolutional network have been presented along to create a simulated realistic world and the results show that the real individual behaviour on a distant planet can be achieved provided the interplanet internet is available as pathway communication.

## **REFERENCE**

- 1. Poondru Prithvinath Reddy: "Metaverse in InterPlanet Internet: Modeling, Validation, and Experimental Implementation ", Google Scholar**