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InterPlanet Computer Network: An Architecture of the Communications Infrastructure with Multiplying Capability

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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. In this paper, we propose an interplanetary internet design architecture to operate successfully and achieve good communication with other planets including the Earth. The architecture proposes network structure which includes Virtual, Cloud, Multiplying and Star set-up to optimize or use few available resources effectively in the network. As it is region based architecture outline, the test results show useful purpose of the design. However, we have not considered delays due to interplanet distances and other factors like Sun's radiation, etc.

INTRODUCTION

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. It also must use the few available resources efficiently in the system.

While IP-like SCPS protocols are feasible for short hops, such as ground station to orbiter, robots to lander, lander to orbiter, probe to flyby, and so on, delay-tolerant networking is needed to get information from one region of the Solar System to another. It becomes apparent that the concept of a *region* is a natural architectural factoring of the Interplanetary Internet.

A *region* is an area where the characteristics of communication are the same. Region characteristics include communications, security, and the maintenance of resources, perhaps ownership, and other factors. The Interplanetary Internet is a "network of regional internets".

What is needed then, is a standard way to achieve end-to-end communication through multiple regions in a disconnected, variable-delay environment using a generalized suite of protocols. Examples of regions might include the terrestrial Internet as a region, a region on the surface of the Moon or Mars, or a ground-to-orbit region.

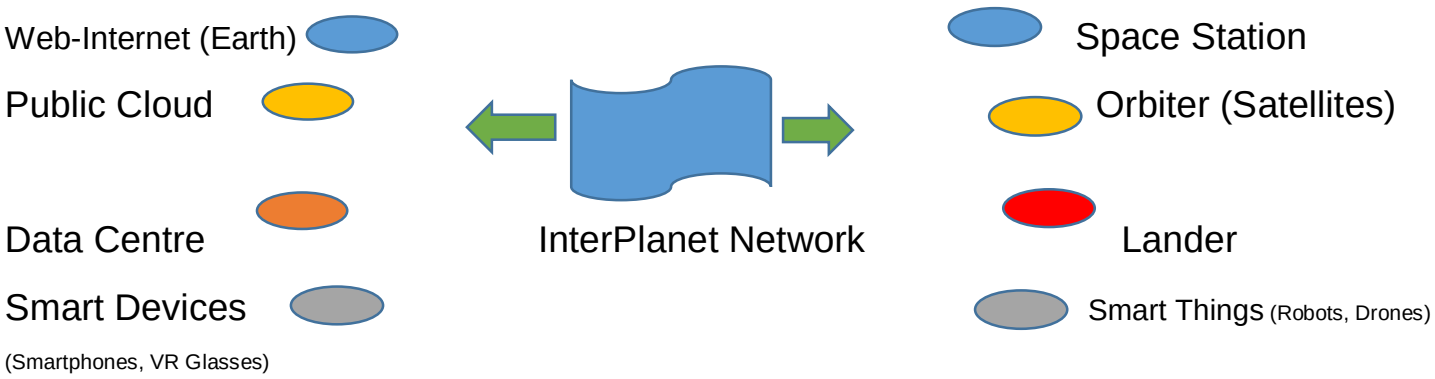
ARCHITECTURE

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.

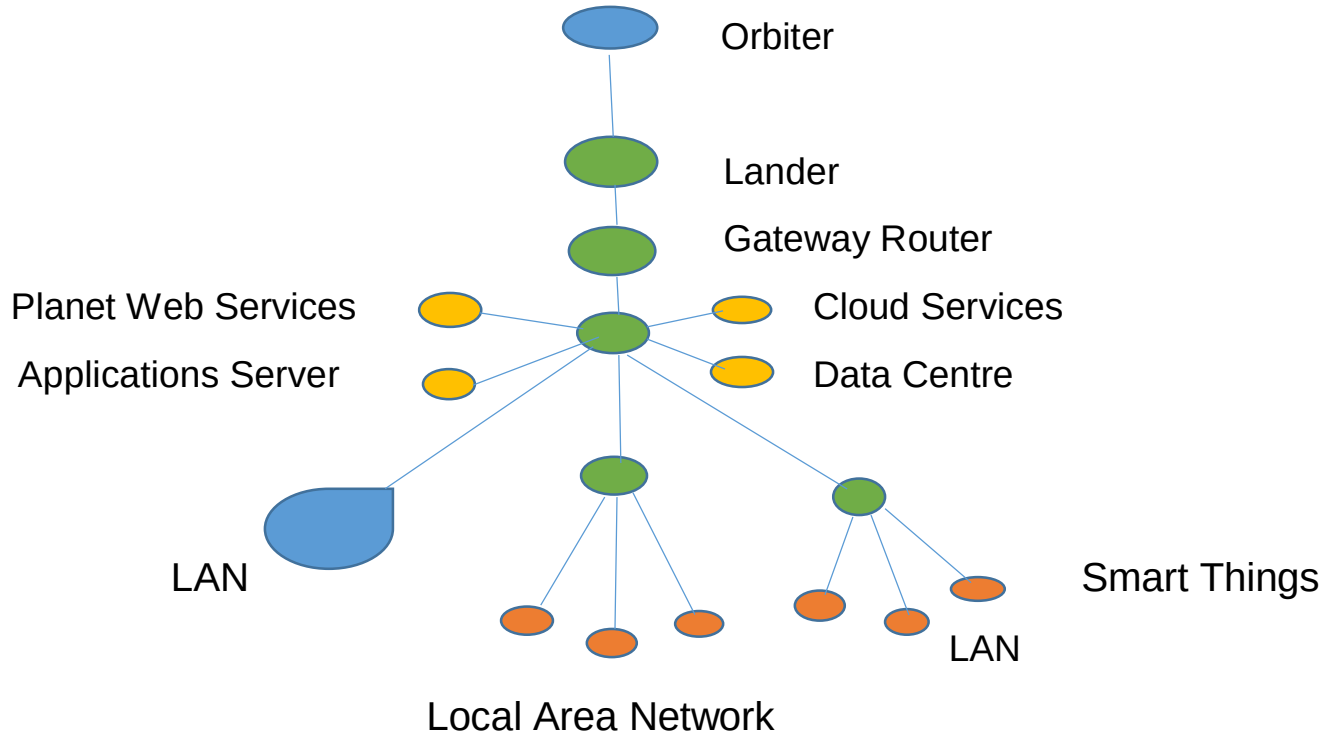
The network architecture for the planet Mars or the Moon is as shown in below figure:-



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.

Elements of planetary network architectures

The planetary network architectures that aid in building and maintaining computer networks for the desired objectives and should offer a complete portfolio of modern network architectures for access, data center, cloud, applications and smart devices.

Goal-based networking

A goal-based network takes desired outcomes as input and sets up the network to achieve these objectives. It does so by automating operations, analyzing network performance, providing all-around security, and integrating with desired operating processes.

Controller-guided

Network controllers are foundation to goal-based networking and are essential to scaling and securing networks in the region. Controllers help respond rapidly to changing operational requirements. They automate networking functions by translating operational goal into device configurations, and they monitor the network devices continuously to help ensure performance and security.

Agent-based

An agent-based network meets desired outcomes and sets up the network to achieve set objectives. Agents respond rapidly to changing business requirements. They automate functions into device configurations and they delegate functions by monitoring network devices continuously.

Multizone

Multiple networks on a planet communicate with one another through their controllers. Such cross-network, or multizone integrations generally involve exchanging relevant operating parameters to help ensure that desired operating outcomes that span networking domains are achieved.

Component-based

Computer networks components comprise both physical parts as well as the software required for installing computer networks at different locations. The hardware components are the server, client, peer, transmission and connecting devices. The software components are operating system, protocols and other application software.

The network can take both peer-to-peer and star topology depending on the application.

Packet-switched

The Protocols are IP (datagrams over Internet) and TCP, DHCP (enables convenient handling of mobile robots, drones, etc.), DNS (Name Resolution) and each protocol

layer should provide service through well-defined interface. The IP protocol provides fragmentation and reassembly of datagrams and error reporting.

The Frame Format includes Address Fields (Source and Destination), Data Field (variable length) and Error Detection Field.

Packet switching transmits data across digital networks by breaking it down into blocks and the network devices can then route the packets to the destination where receiving device reassembles them for use.

The type packet switching used is connectionless (datagram switching).

The protocol used by the Planet Internet is TCP/IP. The IP in TCP/IP stands for Internet Protocol and is the protocol used by computers to communicate with each other. The IP protocol provides fragmentation and reassembly of datagrams and error reporting.

Each IP packet contains both a header(20 or 24 bytes long) and data (variable length). The header includes the IP address of the source and destination plus other fields that help to route the packets. The data is the actual content, such as a string of letters or part of a webpage.

Remote and Native IP packet

The Remote IP interface is defined which lets a remote client program send and receive from its parent an IP packet on any IP protocol and only clients in the endpoint list can use the Remote IP interface.

The Native IP interface lets a client program send and receive arbitrary IP packet on any IP protocol except TCP and UDP. Only one client can use any given protocol at one time. Only clients which are natural and in the obey list can use the Native IP interface.

Virtual networks

A **virtual network** is a **network** of geographically unrelated computers connected together via the internet and Virtual networks form their connections through the internet. Virtual network servers create a network that has no direct physical connection, but one that allows data sharing and communication and to alter the network structure as conditions warrant determined by operational requirements, using software rather than requiring physical changes in connections to the network. When a virtual network is configured, a zone sends traffic to an external host in the same way

as a system without a virtual network. Traffic flows from the zone, through the VNIC to the virtual switch, and then to the physical interface, which sends the data to the network. Virtual network is the core of planetary internet and is essential for participating nodes in operational requirements for efficient use of few available resources on a planet.

Multiplying Networks

Multiplying networks are a class of programmable networks that automate the life cycle process for the creation, deployment and management, and destruction of network architecture. These networks are capable of creating distinct *child* virtual networks with control and management systems at the root of creation. This type of network is created because the deployment of new network services is often required to meet the operational requirements of smart or autonomous agents such as robots, drones, etc.

Multiplying with Delegation

Since there is a limit on number of child nodes the controlling node can support and in that scenario, It is proposed that one of the child nodes to function as a controlling node with delegation from the root node (parent node) for the duration of execution of a task as required by operations. Once the task is complete, the control of the agent node will be passed back to the parent node.

Network architecture defines how the system is broken into parts and how those parts interact. Imagine, for example, constructing a Prefabricated Modular Steel Structure (shed) by a group of robots which is 3D printed structure to be assembled either on the planet Mars or on the Moon. All the required materials are to be transported to the erection site by drones. Each of the group of robots would be performing different functions such as Foundation, Erection, and Roof Fixing. Group of robots performing specific task would down load applications relevant to the task to be performed as per 3D printed sequence of assembly. There may be a situation where a specialist gang of welding robots required to perform welding operations after completion of foundation and this requires establishing communication with the controlling robot of foundation gang and also peer-to-peer connection with the foundation robots. Therefore, creation of such networks require Virtual network with welding robots of having capability of multiplying networks during the life cycle process for achieving desired operational requirements. Since there is a limit in Thread star topology network where a single node cannot serve many child nodes, an agent-based network with delegation from parent node is proposed for the duration of execution of welding task. Once the task is complete, the control will be passed-back to the parent node.

TEST RESULTS

Since, the communication on a planet is in a wireless mode, the connections are made using antenna as a medium to transfer data and no wired NIC using cables and connectors are made to transfer data. In obscene of full blown large-scale wireless network, the network architecture is tested for some features in wired mode with cables and connectors on existing internal internet and the results are not comparable to actual wireless type of network.

CONCLUSION and FUTURE WORKS

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.), and the earth ground stations and linked through Earth's internal internet, and consisted of Virtual, Cloud, Multiplying and Star design. At a region level the architectural design shows useful purpose. However, we have not factored-in interplanet distances and other disturbances like Sun's radiation, etc. on the network communication.

For future works one may expand the network architecture as a standard way to achieve end-to-end communication through multiple regions in a disconnected, variable-delay environment using a generalized suite of protocols. Examples of regions might include the terrestrial Internet as a region, a region on the surface of the Moon or Mars, or a ground-to-orbit region. Also we may try to model by adopting delay-tolerant networking which is needed to get information from one region of the Solar System to another.

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