

Interplanetary Internet: Where no
DNS query has gone before...



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The challenge:

SMTP relies on IP connectivity for normal operation. Inter-planetary mail would necessarily include non-IP based circuits between isolated IP networks due to high latency and lack of continuous end to end links and routes.

Why Not IP?

- Delay - Latency Barrier 3 seconds round trip time.
- Disruption - Non-continuous end to end path.
- Application design generally unsuitable for Delay/Disruption
- Routing Challenges
- Can you dig it?

If not IP, what then? BP!

- RFC 9171 Bundle Protocol; designed for space networks.
- <https://datatracker.ietf.org/doc/html/rfc9171>
- BPv7 specified for LunaNet by NASA in most recent draft.
- <https://www.nasa.gov/wp-content/uploads/2023/09/lunanet-interoperability-specification-v5-draft.pdf>
- Great for robotic missions; human-centric uses are undeveloped.
- Uses ipn: naming scheme URI, not IP addressing.
- <https://www.iana.org/assignments/uri-schemes/uri-schemes.xhtml#ipn-scheme-uri-allocator-identifiers>
- IPN DNS RRTYPE allocated for node identifier portion of ipn: URI.

Wait, I want Internet!

Use cases for Other-Worldly IP Networks:

- Multiple Operators/Administrative Domains present
- DNS, Email, Web - Robust application layer.
- Existing base of skilled operators - familiar to users.
- NTP - Time Distribution

Hybrid Network Solution

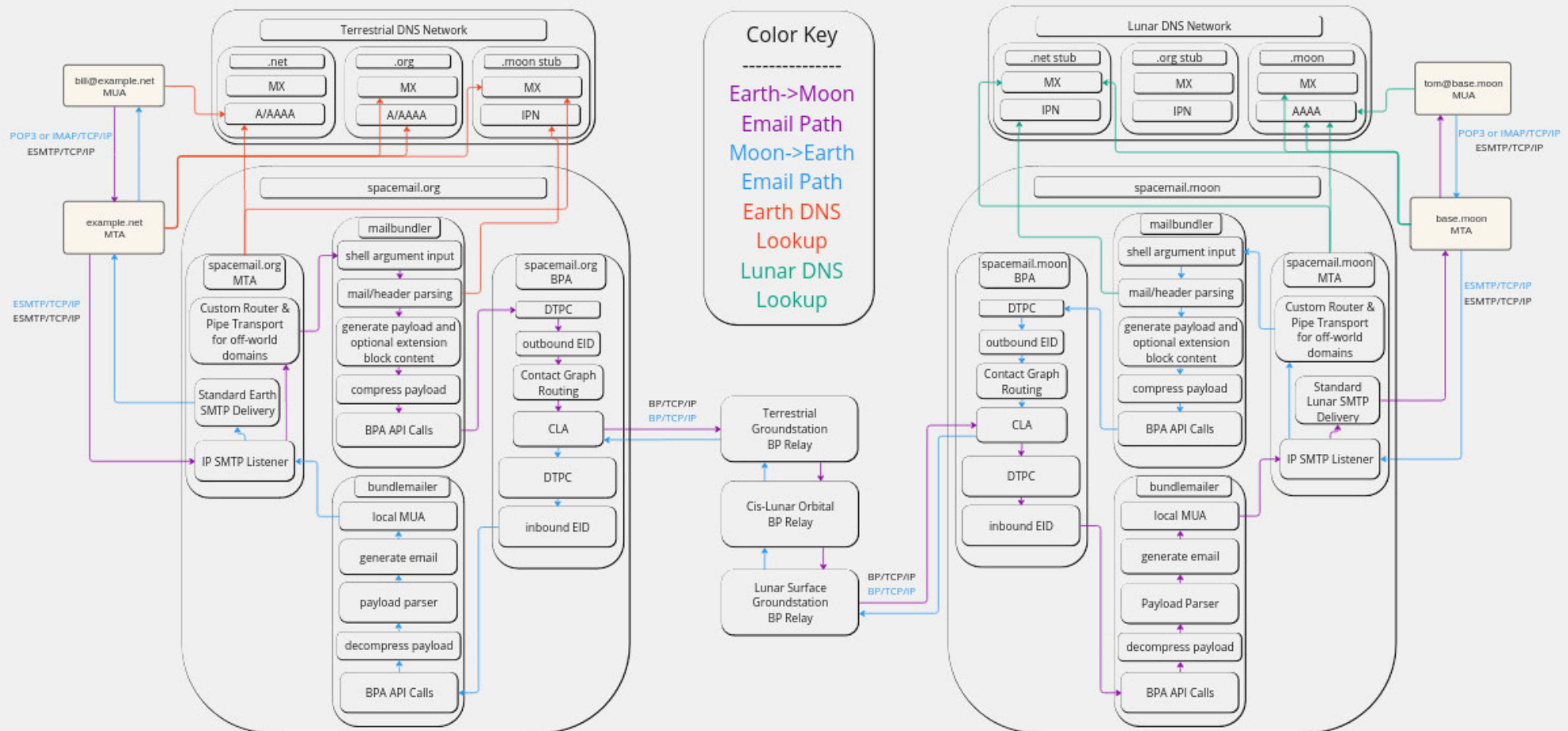
- IP Networks service Earth.
- Discrete, isolated IP Networks service other worlds.
- DTN relays data (not packets) through BP networks between worlds.
- Application Layer Gateways process IP<-->BP network integration.
- IPNXP – InterPlanetary Network Exchange Point

A tale of two roots...

- Per-world DNS Networks
- Same TLD zones, but different data on different worlds.
- Stub data in zones for off-world domains.
- No need to synchronize. Allows local service everywhere.
- No DNS query transits the DTN. No waiting for a reply!

<https://www.spacelypackets.com/smtp.jpg>

Earth \longleftrightarrow BP Network \longleftrightarrow Moon



One of these days, Alice... bang,
zoom! To the moon!

- Internet connected MTA sends mail to tom@base.moon.
- Uses MX record to identify appropriate Gateway MTA.
- Gateway MTA accepts mail for off-world destinations.
- Shim application accepts mail from MTA, sends to BPA.
- BPA accepts mail as bundle payload data, sends off-world

The Eagle has landed.

- Destination BPA accepts bundles containing mail.
- Shim accepts mail from BPA, sends to Gateway MTA.
- Gateway MTA looks up base.moon MX in local DNS.
- MTA looks up IPv6 Address of base.moon MX in local DNS.
- MTA delivers mail to tom@base.moon via SMTP.

Great theory; does it work?

An air gapped simulation environment for development was necessary to prove functional operation of this architecture.

- Simulate terrestrial DNS root so .mars, .moon zones work.
- Simulate Mars DNS root so off-world and local DNS works.
- Simulate multi-hop BP space network.
- Customize MTA operation and write MTA/BPA shims.
- Simulate delay and path disruption in BP network.
- <https://www.spacelypackets.com/uns.jpg>

Temba, his eyes open!



Yes, it works...

```
scott@base: ~  
ALPINE 2.26 MESSAGE TEXT Folder: INBOX(READONLY) Message 1 of 10 ALL ANS  
Return-path: <scott@voyager.spacelypackets.com>  
Envelope-to: scott@base.mars  
Delivery-date: Fri, 01 Nov 2024 03:40:02 -0400  
Received: from [2602:fd2:a::1] (helo=mg.spacelypackets.mars)  
by base.mars with esmtps (TLS1.3) tls TLS_ECDHE_RSA_WITH_AES_256_GCM_SHA384  
(Exim 4.96)  
(envelope-from <scott@voyager.spacelypackets.com>)  
id 006xWK-0007cX-0m  
for scott@base.mars;  
Fri, 01 Nov 2024 03:40:02 -0400  
Received: from scott by mg.spacelypackets.mars with local-bsmtp (Exim 4.98)  
(envelope-from <scott@voyager.spacelypackets.com>)  
id 1t6mFm-000000003an-2m2x  
for scott@base.mars;  
Fri, 01 Nov 2024 07:39:31 +0000  
Received: from [2602:fd2:b::2] (helo=voyager.spacelypackets.com)  
(Exim 4.98)  
(envelope-from <scott@voyager.spacelypackets.com>)  
id 1t6mFm-000000001vC-1aTk  
for scott@base.mars;  
Fri, 01 Nov 2024 07:39:30 +0000  
Received: from scott (helo=localhost)  
by voyager.spacelypackets.com with local-esmtp (Exim 4.96)  
(envelope-from <scott@voyager.spacelypackets.com>)  
id 1t6mED-0007ms-1F  
for scott@base.mars;  
Fri, 01 Nov 2024 03:37:53 -0400  
Date: Fri, 1 Nov 2024 03:37:53 -0400 (EDT)  
From: scott <scott@voyager.spacelypackets.com>  
To: scott@base.mars  
Subject: this is a test  
Message-ID: <f4ce20c2-3464-7e8d-0c04-93220b6a721b@voyager.spacelypackets.com>  
MIME-Version: 1.0  
Content-Type: text/plain; format=flowed; charset=US-ASCII  
  
this is only a test. in a real emergency, this message would contain  
instructions to proceed.  
emailed via intervening BP network, with no direct or indirect IP  
connectivity between source and destination MXes.
```

```
Delivered-To: solaratone@gmail.com  
Received: by 2002:a05:6a20:2c2b:10:10:940:946 with SMTP id g43sp541343p1;  
Sat, 7 Dec 2024 18:30:28 -0800 (PST)  
X-Forwarded-Encrypted: i=2; AJY/CU+hlVP3+0K70863aE0B+ScE+70E1K0+ztScDnAlGdu q0N4/6p4kuqg79a0q08MYZuBR0w0@gmail.com  
X-Google-Smtp-Source: AHFTfEL3S1v8anGmPj16+4+de+H0uVt0a1C0gJ720x75NvSC2p0h0H0H01r1DPC09  
X-Received: by 2002:a05:6902:2c6c:10:10:48e:c29f with SMTP id 3f1490657ef6-aa808c555e5e5980139276.20.1733625928105;  
Sat, 07 Dec 2024 18:30:28 -0800 (PST)  
ARC-Seal: i=1; a=rsa-sha256; t=1733625928; c=none;  
d=google.com; s=arc-20240605;  
b=6Zu2i1ff+2qeez5W8Kq21N0W0Kc00gP0UwD11MxvM3F20P0T2pZ1Ym  
+BSCY0VwL0a0K05XX0m0LA0TWf10F0h0w07Mpy7p0M0C0B0G400A/5100q0K0E  
K0H0Z050e0w+H08592K0X1020L0121031C0d0gC40T1A0hT1u0g0W/147f0pK0V  
j0U70g0P0SjY0W0M7g0A0E0E10W0F0k0e0p0p010d0a0E00100y0u0uL0A  
X0K0K0V0C11W0T3820K0Y1V0E27E0d0u0D0F00/LGZ74gT00q0C0R0p0k0fi+  
P00q0w  
ARC-Message-Signature: i=1; a=rsa-sha256; c=relaxed/relaxed; d=google.com; s=arc-20240605;  
h=tim-version:message-id:subject:to:from:date;  
b=hP0W0t0oP1q2i217040p0u0d15482xLR0p1j0030+;  
f=h211D0u0P0u0qT0Z0F0G1e0h0sc1+7C1U170C21Z10+;  
b=W0V1070Y0g4070A00K0K0J0P0P70H0110P050e0u0R0E0P0C00B0Y0c0L0  
E0c0L0R0V0/0W0g0p10u0L0h0b0r0T0r0040060G0M0C0F0A0q0T0D0v02L0d030a0D0  
00J0d0I0w0L0C4T0T1C0A0K0q0K0l0S0e00p0Y0z0d0h0F0u0jY0b0w0B00y0P0p0  
g0j0q2U0d0N0S+0Sj0g0H0T0F0q340u0h0y0D0q0M0z0y0F050e0R0u0p0a0i0r  
V0L0T0D0C0L0d0Z0x0w0e0r0T0G0A0E0q0W0d0Q0E0H10B4S00q0t+0Sj0U0N0C10g0g  
Y0C0w+  
d=google.com  
ARC-Authentication-Results: i=1; mx.google.com;  
spf=pass (google.com: domain of scott@luna.sol.int designates 2602:fd2:fae:be as permitted sender) smtp.mailfrom=scott@luna.sol.int;  
dmarc=pass (p=REJECT sp=REJECT dis=NONE) header.from=sol.int  
Return-Path: <scott@luna.sol.int>  
Received: from durpa.spacelypackets.com (durpa.spacelypackets.com. [2602:fd2:fae:be])  
by mx.google.com with ESMTPS id 3f1490657ef6-aa808c555e5e59801392454276.322.2024.12.07.18.30.28  
for <solaratone@gmail.com>  
(version=TLS1.3 cipher=TLS_AES_256_GCM_SHA384 bits=256/256);  
Sat, 07 Dec 2024 18:30:28 -0800 (PST)  
Received-SPF: pass (google.com: domain of scott@luna.sol.int designates 2602:fd2:fae:be as permitted sender) client-ip=2602:fd2:fae:be;  
Authentication-Results: mx.google.com;  
spf=pass (google.com: domain of scott@luna.sol.int designates 2602:fd2:fae:be as permitted sender) smtp.mailfrom=scott@luna.sol.int;  
dmarc=pass (p=REJECT sp=REJECT dis=NONE) header.from=sol.int  
Received: from scott by durpa.spacelypackets.com with local-smtp (Exim 4.96) (envelope-from <scott@luna.sol.int>) id 1tK6rF-0002Y0-13 for solaratone@gmail.com; Sat, 07  
Dec 2024 21:17:17 -0500  
Received: from scott (helo=localhost) by luna.sol.int with local-esmt (Exim 4.96) (envelope-from <scott@luna.sol.int>) id 1tK73s-0002Y0-20; Sun, 08 Dec 2024 02:30:29  
+0000  
Date: Sun, 8 Dec 2024 02:30:29 +0000 (UTC)  
From: scott@luna.sol.int  
To: <solaratone@gmail.com>, <durpa.spacelypackets.com>, <scott@luna.sol.int>  
Subject: luna.sol.int live  
Message-ID: <0Bac073-7794-e280-60fc-30fc3046007@luna.sol.int>  
MIME-Version: 1.0  
Content-Type: text/plain; format=flowed; charset=US-ASCII  
  
Hi Vint and Randy,  
This mail passed through a Bundle Protocol network to reach the Internet.  
The BP Application Layer Gateway system for SMTP provided this  
functionality. luna.sol.net represents the lunar gateway.  
This is a test. It has been determined that further configuration is  
necessary to parse multipart/mixed encoding, so while we can receive email  
from gmail, we cannot read the body of the mail at this account. I can  
read replies in the copied email accounts, however. Debugging ensues.  
(for posterity)  
Scott Mitchell Johnson  
Spacely Packets, LLC
```


...mostly :)

Source Image
received!



Attachment



Prior to implementation of reliability and in-order delivery layer,
DTPC (Delay Tolerant Payload Conditioning).

Rules of Acquisition

- Routers with onboard storage – BP “store and forward.”
- Terrestrial Gateway/cache services/servers.
- Lunar Orbital Relays.
- Lunar Surface optimized network infrastructure.
- Lunar Surface cache/content servers – pure data warehousing.
- Optical deep space network capacity – LCOT.
- IP Application porting/protocol updates.
- Bundle Protocol Agent development/features.

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Temporal Prime Directive

- Planning horizon – start now.
- Design for application interoperability with terrestrial Internet, isolated Internet, and BP network architecture.
- New services require new/additional specialized infrastructure.
- Space agencies plan based on accepted standards/solutions of today for missions 5-10 years from now.
- Existing space networks over-subscribed, capacity required to support planned missions.

Live long and prosper.

Contact info:

- scott@spacelypackets.com

For more information:

- RFC 9171 current BP spec.
- DTN WG of IETF
- IPNSIG Academy -->

