



Interplanetary Networking Special Interest Group Pilot Projects Working Group

Achievements 2022



Interplanetary Networking Special Interest Group

Pilot Projects Working Group - PWG

Achievements Report 2022

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Dear Reader,

On behalf of the IPNSIG, the Interplanetary Chapter of the Internet Society and the Pilot Projects Working Group of the IPNSIG, I am very happy that you are interested in the evolution of the Interplanetary Internet.

Year 2022 was very active for the IPNSIG Pilot Projects Working Group.

The developments that you will read about in this report are the result of the efforts and commitment of the members of the Group and that we are pleased to share with you.

We would like to hear from you on our websites and you can also be part of the development of the Interplanetary Internet.

Hoping that you enjoy this report on our works,

Sincerely,

Oscar Garcia

Pilot Projects Working Group Lead

ISOC Interplanetary Chapter

IPNSIG Board Member.



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Oscar Garcia - PWG Lead

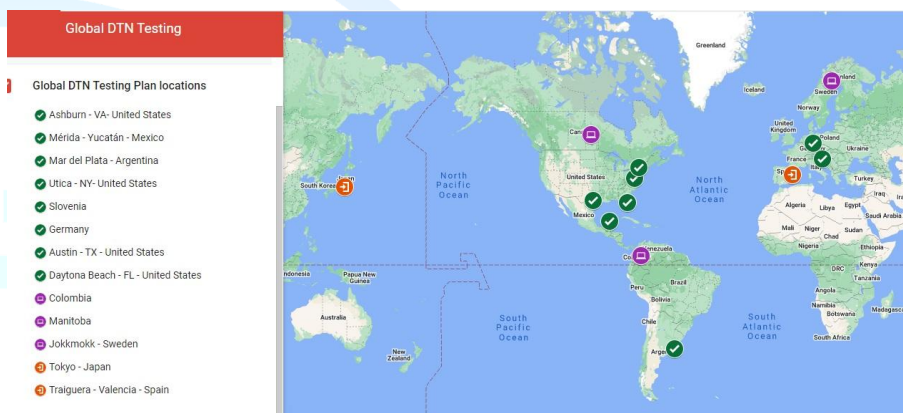
The Pilot Projects Working Group DTN Network

In 2022, the Pilot Project Working Group started and developed the first global DTN Network.

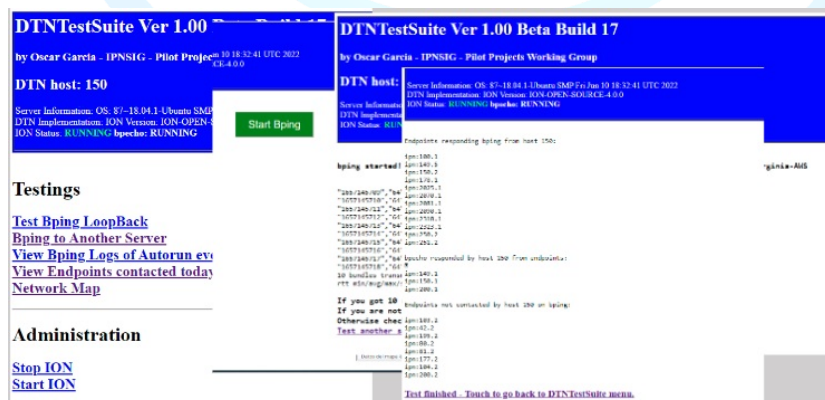
The PWG Network expanded to cover several countries including technologies to test the different DTN implementation based on the Bundle Protocol and tested several tools, also described in the current report

It is a goal of the Projects Working Group to include satellite and Space communications in the near future. Servers in cloud systems, personal computers, small board computers and on premise computer systems are part of the PWG network, allowing to test DTN applications and technologies in a varied environment.

<http://pwg.ipnsig.space> Option DTN Testing Plan.



DTNTestSuite Web



The DTNTestSuite is a tool developed by Oscar Garcia to test DTN implementations in various environments. It is applied in the PWG Network to check connectivity of the several DTN nodes.. In 2022, a Web Interface has been added to the DTNTestSuite, allowing easier use for operators.



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IPNSIG Academy Presentation

On Wednesday July 13 2022, the Interplanetary Networking Special Interest Group (IPNSIG) presented the third IPNSIG Academy session on. 'Delay and Disruption Tolerant Protocol (DTN) Projects'. Oscar Garcia, IPNSIG Board Member and Projects Working Group Lead hosted by Dr. Scott Pace, Director, Space Policy Institute, George Washington University, with the PWG team, talked about various Delay/Disruption Tolerant Networking (DTN) developments currently underway, including the International IPNSIG DTN Network, running applications and planned projects applying the Interplanetary Internet technologies.



NASA DTN Industry Day Presentations

NASA collaborates with external entities such as the InterPlanetary Networking Special Interest Group (IPNSIG) which has been working for over 20 years to expand the internet into space. IPNSIG works to promote the development, maturity, and adoption of DTN for both interplanetary and terrestrial use. In these presentations in January and September 2022, several IPNSIG PWG DTN developments were presented including multicasting on DTN, delay-tolerant video streams, Artificial intelligence federated learning in distributed servers on DTN and the PWG Network.





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Following these briefings the IPNSIG team discussed collaboration activities with the NASA DTN community.

You can watch the presentations in the following link at NASA:

https://www.nasa.gov/directorates/heo/scan/engineering/technology/disruption_tolerant_networking_collaboration

Alberto Montilla Bravo & Alberto Montilla Ochoa

Spatiam DTN Manager

Serving the PWG network for delivery of contact plans and configuration files, including the delivery of a management endpoint to connect ION-based instances to the Spatiam DTN Manager for configuration updates.

Name	EID	Address	Port	CL	Impl.
Spatiam Echo	10			LTP	ION
New York	2			LTP	ION
New York	25			LTP	ION
net	23			LTP	ION
(ADKCT)	42			LTP	ION

Interoperability tests between ION and μ D3TN

Worked to perform basic application interoperability tests between ION and μ D3TN to integrate D3TN into the PWG network successfully.

<https://www.spatiam.com/>



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Samo Grasic

ION-DTN Network Information Exchange Mechanism (DTNEx)

```
Main loop...
Timestamp: 2022-11-22 22:18:34
List of configured plans:
>88
>80
>177
>81
>150
>20423921
>1
>5
Skipping local loopback plan
Messaging own plan to node [Origin:88, From:88, To:80, About:88]
Messaging own plan to node [Origin:88, From:88, To:177, About:88]
Messaging own plan to node [Origin:88, From:88, To:81, About:88]
Messaging own plan to node [Origin:88, From:88, To:150, About:88]
Messaging own plan to node [Origin:88, From:88, To:20423921, About:88]
Messaging own plan to node [Origin:88, From:88, To:1, About:88]
Messaging own plan to node [Origin:88, From:88, To:5, About:88]
Link message received[Origin:80, From:80, NodeA:80, NodeB:88]: update ION...
Forwarding message[Origin:80, From:80, To:177, NodeA:80, NodeB:88]
Forwarding message[Origin:80, From:80, To:81, NodeA:80, NodeB:88]
Forwarding message[Origin:80, From:80, To:150, NodeA:80, NodeB:88]
Forwarding message[Origin:80, From:80, To:20423921, NodeA:80, NodeB:88]
Forwarding message[Origin:80, From:80, To:1, NodeA:80, NodeB:88]
Forwarding message[Origin:80, From:80, To:5, NodeA:80, NodeB:88]
Link message received[Origin:80, From:80, NodeA:80, NodeB:88]: update ION...
Forwarding message[Origin:80, From:80, To:177, NodeA:80, NodeB:88]
Forwarding message[Origin:80, From:80, To:81, NodeA:80, NodeB:88]
Forwarding message[Origin:80, From:80, To:150, NodeA:80, NodeB:88]
Forwarding message[Origin:80, From:80, To:20423921, NodeA:80, NodeB:88]
Forwarding message[Origin:80, From:80, To:1, NodeA:80, NodeB:88]
Forwarding message[Origin:80, From:80, To:5, NodeA:80, NodeB:88]
Generating new graph visualization...
Updated Contact Graph List:
node 1 to node 88
node 5 to node 88
node 80 to node 88
node 81 to node 88
node 88 to node 1
node 88 to node 5
node 88 to node 80
node 88 to node 81
node 88 to node 88
node 88 to node 88
node 88 to node 150
node 88 to node 177
node 88 to node 20423921
node 150 to node 88
node 177 to node 88
node 20423921 to node 88
Sleep for 60 sec...
```

Unlike most of the space missions where the DTN network topology and connectivity can and need to be scheduled in advance, terrestrial applications of DTNs will need to cope with more dynamic network topologies. In order to tackle the challenge of dynamic network topologies a DTNEx protocol prototype was designed. As the majority of the nodes in the IPNSIG network are running the ION DTN implementation, the first DTNEx prototype was implemented as a Bash script that users can run together with the ION. The script does not require any configuration and is able to extract the node configuration data directly from the running ION node.

Furthermore, the DTNEx allows IPNSIG to build up and test more complex DTN topologies (beyond the standard one-to-one mesh) and DTN regions.

The DTNEX script registers additional ipn endpoints on the preset service number 12160. This service number is then used to receive network information messages from other nodes, using the built in bpsink service that runs in the background. The main loop of the DTNEX script periodically (set up using updateInterval value) sends information about configured ION induct and outduct plan (directly connected DTN nodes – neighbor nodes) to all the neighboring nodes. After, the script parses received network information messages from others nodes and updates a local ION Contact Graph accordingly. At the same time, the received network messages are forwarded further to other nodes.



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UART and LoRa DTN Convergence Layer for ION-DTN implementation

In order to build and run the DTN bundle protocol over less conventional data links, an UART Convergence layer was added to the ION-DTN implementation. In turn, this convergence layer allows us to run bundle protocol over many legacy standards (like RS-232, RS-485, old telephone modems, radio/optical links, etc). This diverse set of data links allows for more rugged testing of bundle protocol.

Furthermore, this convergence layer will allow usage and tests of ION-DTN bundle protocol implementation over the existing Dalvadis reindeer tracking LoRa-DTN network.

The UART Convergence Layer was implemented on the latest version of ION-DTN implementation. Using an UDP convergence layer as a boilerplate, the UART convergence layer uses a standard POSIX terminal control library. A bundle data stream is send directly to a preconfigured tty device. In order to make this communication transparent, a serial timeout function (preset to 0.1 sec) is used on both sides of the UART interface.

The implementation also includes a minimal Arduino LoRa radio sketch that can be used for point-to-point links or as a template for further LoRa radio stacks (that will have to include data flow control, buffering, CRC, etc).

The code is available here:

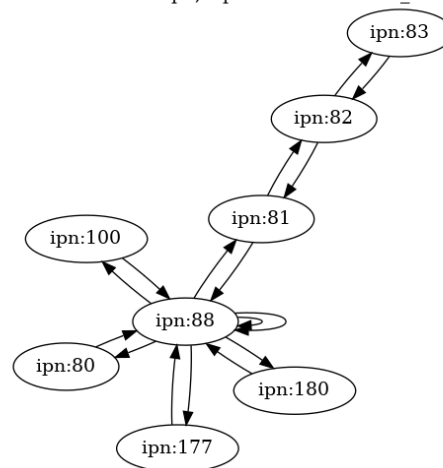
<https://github.com/samograsic/ION-DTN-Uart-LoRa>

DTN Contact Graph Visualization

As the DTN network grows and the contact graph topologies are increasingly complex, a visual overview of the DTN network topology is useful for troubleshooting and testing purposes.

An ION-DTN contact graph generator is implemented using the bash script that queries ION's contact graph and generates a PNG image of a graph using the open sourced Graphviz visualization software (<https://graphviz.org/>).

IPNSIG Network Graph, Updated:2022-06-17_02-07-49





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The DTN contact graph generator was embedded into the latest version of DTNex script and is available here:

<https://github.com/samograsic/ion-dtn-dtnex>

Scott Burleigh

ION-DTN Experimental - IONe

Integrating multiple new ION feature branches from multiple PWG members into a unified ION experimental baseline distribution; release of initial version is targeted for mid-January.

<https://sourceforge.net/projects/ione/>

Scott Johnson

IPv6 Port of ION Library Functions and CLAs

Completed several IPv6 specific library functions, primarily housed in `ici/library/libip6.c`, as well as several of the corresponding Convergence Layer Adapters which call these functions. This code was posted to a sourceforge hosted git repository, and merged into the first release of ION Experimental (IONe) which incorporates changes from several authors. Among these the UDPCLA, TCPCLA, and UDPLSA for LTP were merged, with the STCPCLA written and planned for later merge.



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IONe-1.0.0 Release Preparation

Significant testing/debugging of the first IONe release, including staging with a wide range of hardware architectures, packaging components for OpenWRT integration, and porting of some IRF components to 32-bit architectures. This release preparation effort also entailed integrating many of the new changes extending ION-4.1.1 into the autoconf build system.

<https://sourceforge.net/projects/ione/>

Spacely Packets

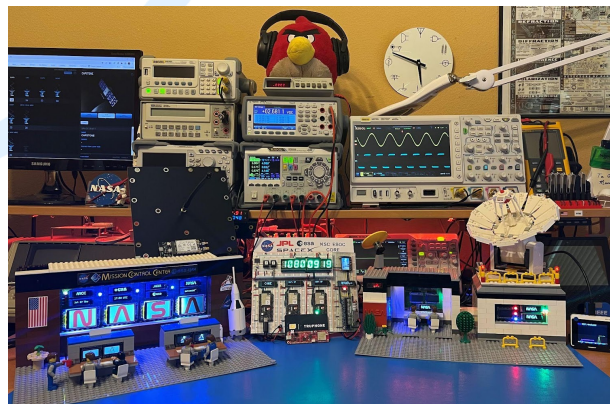
Spacely Packets, LLC was stood to house the operation of a research and development project integrating ION with an Internet router announcing IPv4 and IPv6 address blocks, which was demonstrated at IETF115. This router is numbered as well with unique CBHE Node ID's, the current naming convention for IPN nodes, as well as IPv4 and IPv6. These ID's were the first ID's assigned by IANA beyond SANA's initial allocation.

<http://www.spacelypackets.com/>

Jorge Amodio

IPN DTN R&D and Education Lab

The experimental Lab during 2022 grew from a handful of DTN nodes to about 50, most of them running on various flavors of Linux, 30 of them running NASA's JPL ION 4.1.1. ION has been tested in 16 different platforms/configurations. Most of the ION nodes run on Single Board Computers (SBC) like the Raspberry Pi or similar. A small contribution was made to update the build script to include ARM64 platforms running in 64 bits mode. Several alternative SBCs have been tested



www.ipnsig.org
<http://pwg.ipnsig.space>



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running ION, results have been documented and shared on the Blog.

Research and Testing

Still work in progress, two nodes are running μ D3TN and another two HDTN from NASA GRC, interoperability tests are expected to start in Q1 2023. One node is now dedicated to monitor 24/7 the local network using the Zabbix package that provides visual representation and reports with information stored in a MySQL database. Currently developing specific scripts to perform various tests using BP, LTP, etc. Some nodes of the IPNSIG network are being monitored by this tool. DTN traffic exchanged with this node is constantly inspected with WireShark for debugging and support purposes.

Outreach & Documentation

Preliminary engagement with several international schools and universities interested to learn more about DTN, IPN, SSI, etc., some of them initiating various projects where I'm looking to provide mentoring and support. A Blog, YouTube Channel are already available, expecting more frequent updates during 2023. A reddit community (not active yet) has been created for discussions about technologies for interplanetary networking. A paper and other documentation is in the works. Active participation on the IETF DTN Working Group.

For more information <http://ipndtn.ljcv.net/>

Boštjan Grašič (MEIS d.o.o., Slovenia)

Cross-compiling ION implementation for OpenWrt

The OpenWrt is a Linux operating system targeting embedded low-power devices. There are approximately 2000 different devices officially supported by OpenWrt where network devices are dominating. Embedded devices running OpenWrt usually do not have sufficient resources to natively compile applications. Therefore a cross-compile environment must be set up on a standard personal computer running Linux to produce applications for target embedded devices. In November 2022 MEIS made with help from Scott Burleigh and Scott Johnson a successful cross-compilation of The Interplanetary Overlay Network (ION) software distribution for Atheros AR9331 based embedded devices running OpenWrt version 19 with minor adjustments. All



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needed adjustments were reported to the administrators of the ION code to be used for further development of the ION and for creating standard build procedures for OpenWRT package of ION for different architectures.

Using ION for environmental data transfer from Sweden to DTN testbed in Slovenia

First operational environmental data transfer between Sweden tested (operated by Samo Grašič) and Slovenian tested (operated by MEIS) using ION DTN implementation over legacy internet has been established since 17th June 2022. The source of data is the environmental station in the town of Lit, Sweden where data is measured on a meteorological station and on lake buoys. At present meteorological data are transferred to the MEIS testbed in Slovenia to a node in the town of Grosuplje. CCSDS File Delivery Protocol CFDP is used with the configuration settings provided by Alberto Montilla Ochoa from SPATIAM. The transferred meteorological data and delays are visible on the website of the testbed <http://www.meis.si/testbed/>.



Preparing ION implementation for Postojna cave testbed

Within the scope of the research project Micrometeorology of Postojna Karst cave MEIS has implemented a DTN testbed for meteorological data transfer from remote locations of the cave. The cave has 20 kilometers of tunnels, 6 km are tourist routes. A small train brings tourists into the heart of the cave. Train drives by two meteorological stations with the names Vodopad and Pisani rov. The train has a data mule mounted on itself. The mule on the train takes data during "drive by" – without stopping at the meteo





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stations. At the end of its route the train mule delivers data to Kongresna dvorana station that serves as a gateway to legacy internet. The transfer is done several times per day and delays greatly depend on the hour of the day because of the train schedule. The mule is based on Atheros AR9331 embedded computer running OpenWrt operating system. Currently PLUTI (Prophet) DTN implementation is used in testbed. The transferred micrometeorological data from cave and delays are visible on the website of the testbed (as line graphs and as sunflowers, <http://www.meis.si/jamca/>). Currently work is intensively underway to migrate to ION DTN implementation in the near future. For this migration cross-compiled ION code for OpenWrt is already being tested on a simple laboratory testbed consisting of three nodes. The configuration for this laboratory testbed has been made using SPATIAM's DTN Manager provided by Alberto Montilla and Alberto Montilla Ochoa.

Acknowledgement

The authors acknowledge that the project ("Dynamics and distribution of CO₂ in karst vadose and epiphreatic zone", ID J7-4630,) was financially supported by the Slovenian Research Agency.

Juan Fraire

μD3TN node in the PWG Network

Developed and integrated μD3TN nodes to the PWG Network and collaborated in the development of D3TN GmbH tools for establishing interoperability and connectivity tests with the PWG Network and in the integration of the DTN Manager by Spatiam Corporation.

<https://d3tn.com/>



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Facundo Novik

Development of CRM for the PWG Network

Created a CRM to follow up new users, this gives the opportunity to share the information about what happened between different managers of support and take better options to resolve any inconvenience.

Support form for new users of the PWG Network

Created form for new users of the PWG Network to request help and support. This support form allows managers to follow up and resolve the difficulties.

This form is available in ipnsig blog, link: <https://ipnsigpwg.blogspot.com/p/support.html>

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