



Field-tests for Demonstrating Low-Cost
World-Wide LEO Communication Networks
Leveraging DTN Protocols
(5th ESA CubeSat Industry Days / 2021-06-01)

DTN
COMMUNICATE BEYOND FRONTIERS

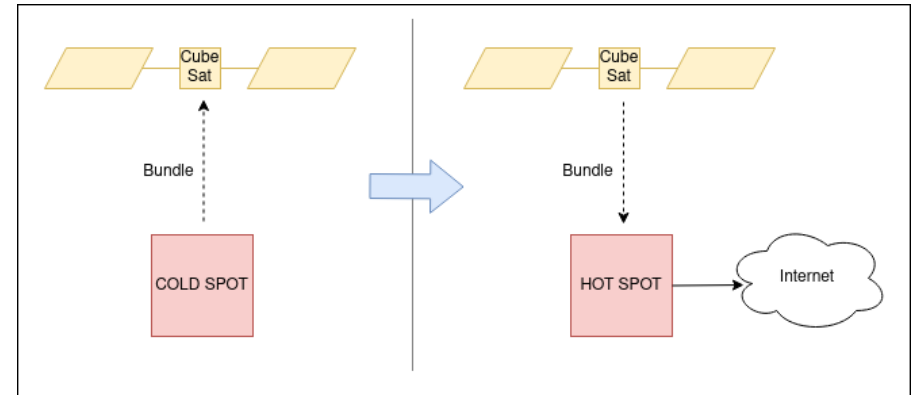


Agenda

- 1) Overview & Goals of Field-Tests
- 2) Overview of μ D3TN
- 3) OPS-SAT Field-Tests
- 4) Conclusion

Overview & Goals of Field-Tests

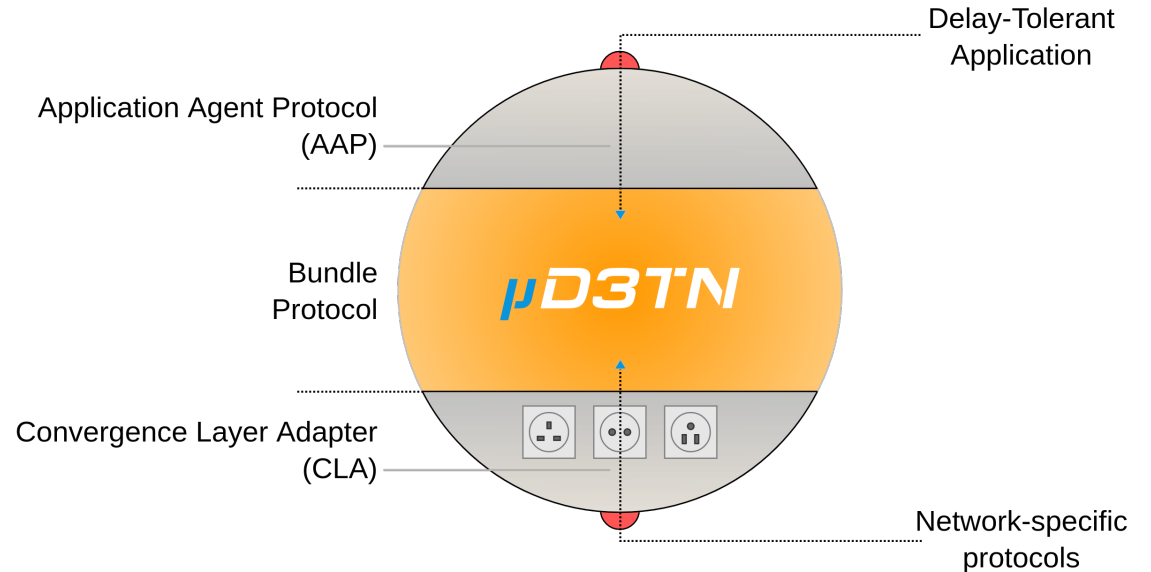
- Overall goals:
 - Demonstrate „Ring Road“ concept leveraging DTN protocols and LEO satellites such as CubeSats for rendering possible low-cost world-wide communication
 - Test version 7 of the Bundle Protocol in space
 - Evaluate own DTN protocol implementation μ D3TN within a non-trivial field-test



- First field-test has been conducted leveraging ESA's OPS-SAT in December 2020
- Extended testing for was done from 2021-05-21 to 2021-05-24

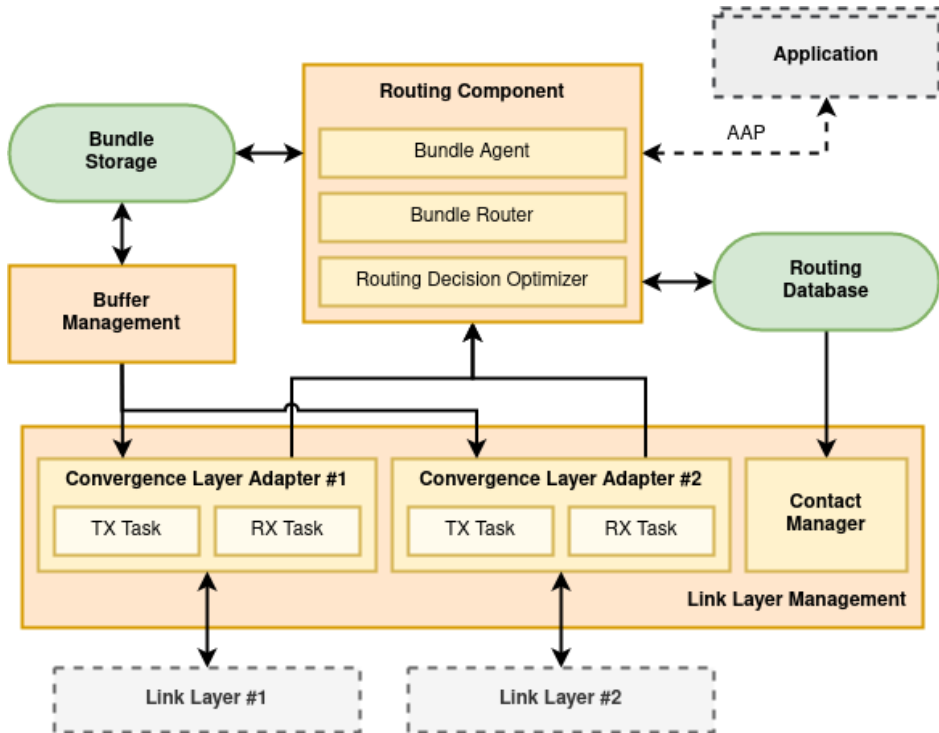
μD3TN - Overview

- μD3TN is an open-source DTN protocol implementation based on μPCN created in 2014
- First BPv7 implementation that has been created (mentioned under the name μPCN in BPv7 draft specification)
- Modular design offering several convergence layer adapters
- Simple integration of delay-tolerant applications due to Application Agent Protocol



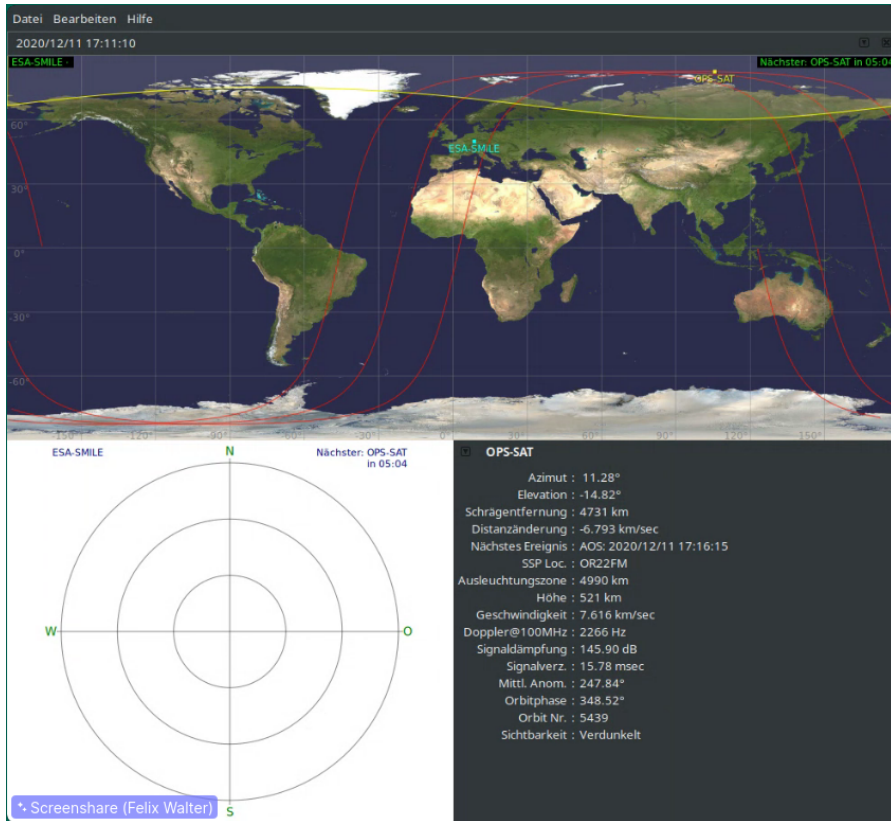
Source code available via:
<https://gitlab.com/d3tn/ud3tn>

System Architecture of μ D3TN



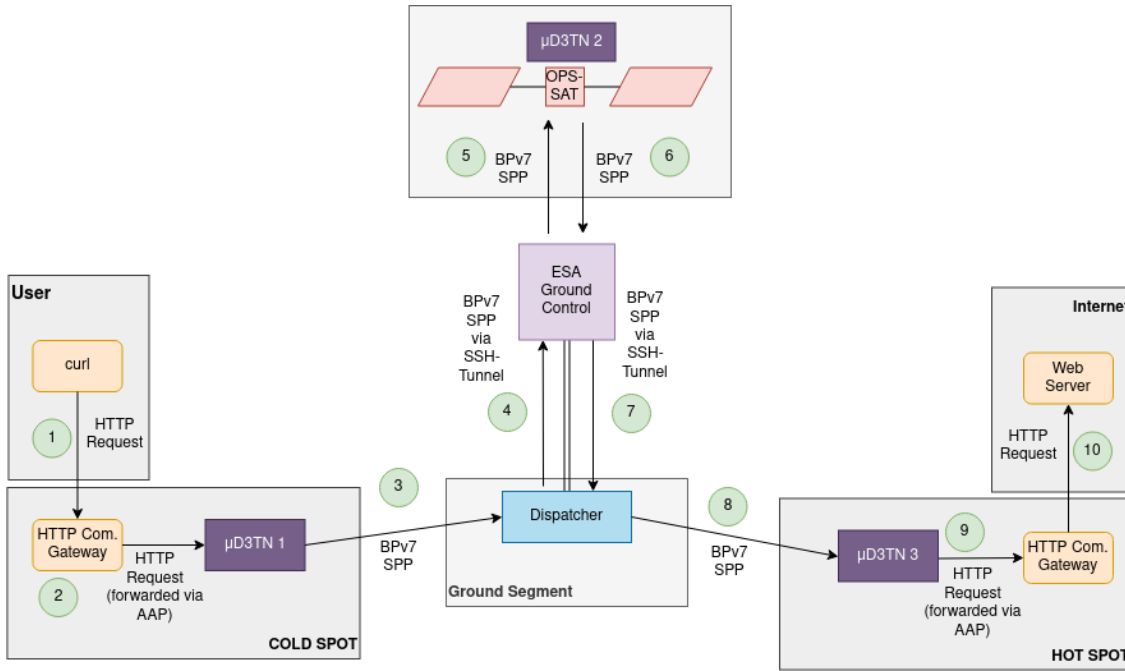
- ▶ Modular design has been used which renders adaptation to various application scenarios possible
- ▶ Convergence Layer Adapters can be easily added to the system
- ▶ Routing, Neighbor Discovery and Buffer Management is provided independently from the underlying link

ESA OPS-SAT



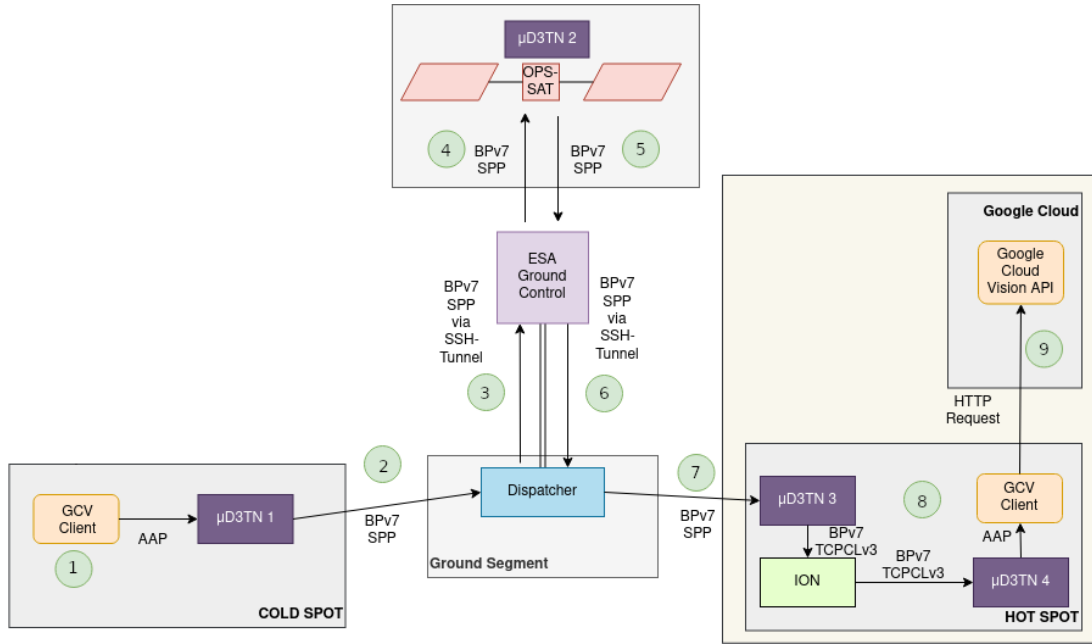
- ▶ 3U CubeSat launched in December 2019
- ▶ Leverages Critical Link MityARM 5CSX with Dual-core 800 MHz ARM Cortex-A9 processors operating Linux
- ▶ Offers TCP interface to communication subsystem → SPP is transferred via TCP by the on-board μ D3TN instance
- ▶ Access to space segment via ESA SMILE Lab leveraging a reverse SSH port forwarding setup

Scenario 1: Access to Web Server



- ▶ D3TN has prepared an experiment for ESA OPS-SAT demonstrating a low-cost world-wide communication system leveraging LEO satellites ("Ring Road Network")
- ▶ First test of Bundle Protocol version 7 in space
- ▶ Experiment leveraged μD3TN on ground as well as on the satellite

Scenario 2: Interoperability Test & Access to Cloud Service

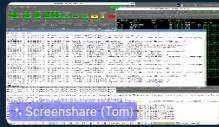


- ▶ Base version shown on the previous slide has been extended to
 - demonstrate compatibility of μD3TN's BPv7 implementation with ION (DTN protocol implementation developed by JPL/NASA)
 - demonstrate access from a Cold Spot to Cloud services

Operations Mode During Passes

```

d [d3tn@opsat:~/opsat]$ ./opsat.py --experiment d3tn --colspot d3tn --colspot d3tn --colspot d3tn --colspot d3tn --colspot d3tn
Sending KMLfile...
python /home/d3tn/opsat-experiment.git/d3tn/tools/aa/aa_receive.py --socket /tmp/colspot.socket --count 1 --append sink
Waiting for bundles...
Received bundle from "d3tn://d3tn-hotspot.d3tn/source": Hello u03TN
Expected amount of bundles received, terminating
Stopping all started processes...
./opsat.py --experiment d3tn --colspot d3tn --colspot d3tn --colspot d3tn --colspot d3tn --colspot d3tn
Starting Ground Station Dispatcher...
Starting u03TN Hotspot-1...
Starting u03TN Hotspot-2...
Starting D3TN Colspot...
Starting D3TN-Web Forwarding Proxy...
Starting D3TN-Web Reverse Proxy...
Process ID: 13048 13056 13051 13052 13079 13080
u03TN must be started on the OPS-SAT. Press enter to continue
Configure GSD stations:
Configure GPS Warmup Contact
Configure GSD experiment contacts
Configure warmup contact between Hotspot-1 and OPS-SAT...
Configure colspot contacts
Configure u03TN Hotspot-1...
Configure u03TN Hotspot-2 contacts
Configure OPS-SAT contacts...
Maximum Duration: 34
http proxy=localhost:7878 curl --max-time 36 http://d3tn.com/hl/
html
<html>
<head>
<title>Hello u03TN</title>
<stylebody { width: 600px; margin: 0 auto; text-align: center; font: 40px sans-serif; font-weight: 600; }>
</head>
<body>
<div class="blue">opsat-D3TN</div>
<strong>Hello from opsat</strong></p>
</body>
</html>
Stopping all started processes...
Your screenshare (Du) --experiment.git/flatsat-scripts
  
```



ESA-SMILE

Nächster OPS-SAT in 01:28:25

OPS-SAT

OPS-SAT	
Azimum	: 223,81°
Elevation	: 63,88°
Schrägentfernung	: 584 km
Distanzänderung	: 2,723 km/sec
Nächstes Ereignis	: LOS: 2021/05/22 17:57:35
SSP Loc.	: JN38EH
Ausleuchtungszone	: 5026 km
Hohe	: 529 km
Geschwindigkeit	: 7,600 km/sec
Doppler@100MHz	: -908 Hz
Signaldämpfung	: 127,73 dB
Signalverz.	: 1,95 msec
Mittl. Anom.	: 165,26°
Orbitphase	: 232,40°
Orbit Nr.	: 7894
Sichtbarkeit	: Tageslicht

FW D MN G AM T VZ M



Selected Take-Aways

- ▶ DTN protocols / BPv7 worked without issues. Interoperability between ION and μ D3TN has been confirmed.
- ▶ Especially on the CLA side thorough interoperability testing is necessary for satellite DTNs. For example, we had to add transmission rate limiting and additional filtering mechanisms to our CLA for the Space Packet Protocol. All I/O code has to be extremely fault-tolerant as unexpected as well as corrupted/partial data may be received at any time.
- ▶ One-way communication solely based on transmission time is a huge challenge, especially because it 1) needs well-synchronized clocks and 2) assumptions have to be made of when a link is present. We enhanced our setup with a periodic retry based on "ping"-like messages, which improved reliability.

Participants & Supporters

- ▶ D3TN GmbH: <https://www.d3tn.com>
- ▶ SPATIAM CORPORATION: <https://www.spatiam.com>
- ▶ From the OPS-SAT team: David Evans, Tom Mladenov and Vladimir Zelenevskiy
- ▶ Lara Suzuki, Computer scientist and member of IPNSIG
- ▶ Vint Cerf, Internet Pioneer
- ▶ Scott C. Burleigh

Thanks for your attention!
contact@d3tn.com

D3TN
COMMUNICATE BEYOND FRONTIERS

 **SPATIAM**

