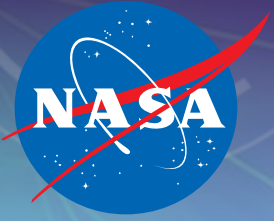


DTN Applications

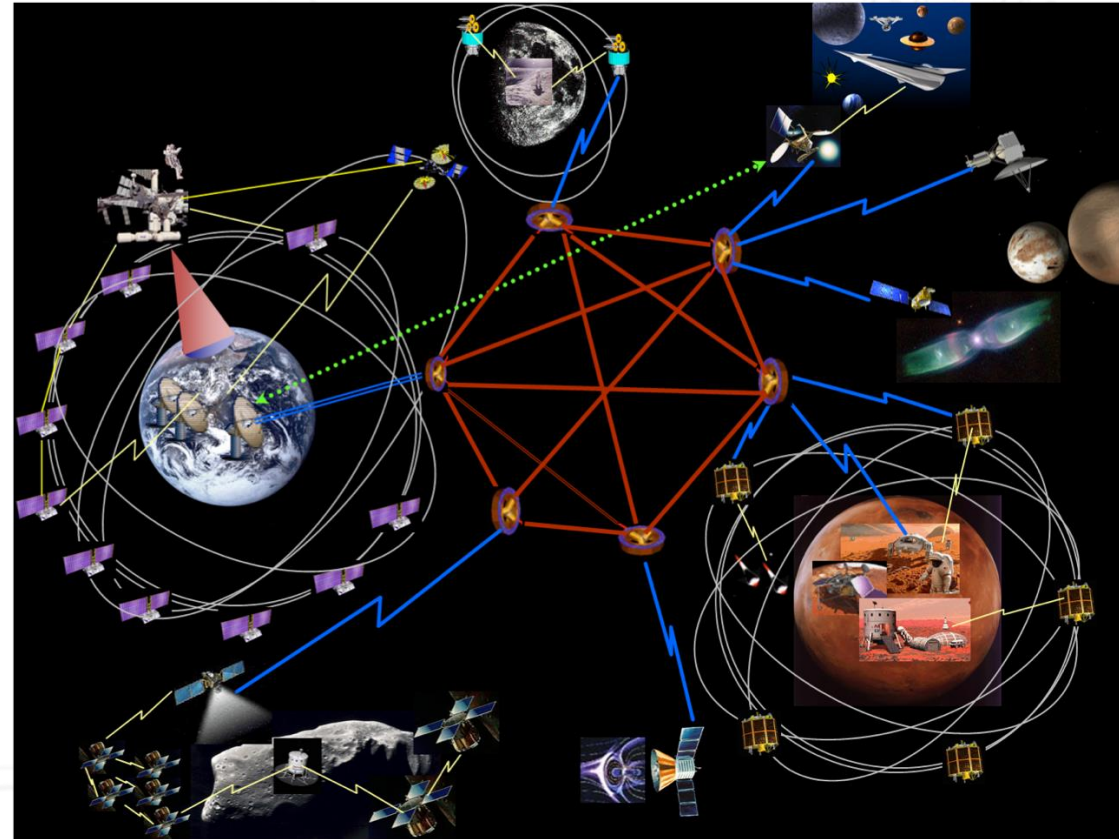
IEEE Workshop on Optimizing Interplanetary
Communication Through Network Autonomy
August 22nd, 2024
Ohio Aerospace Institute, Cleveland Ohio

Nadia Kortas
Shaun Mckeehan
Timothy Recker
NASA Glenn Research Center

Solar System Internet



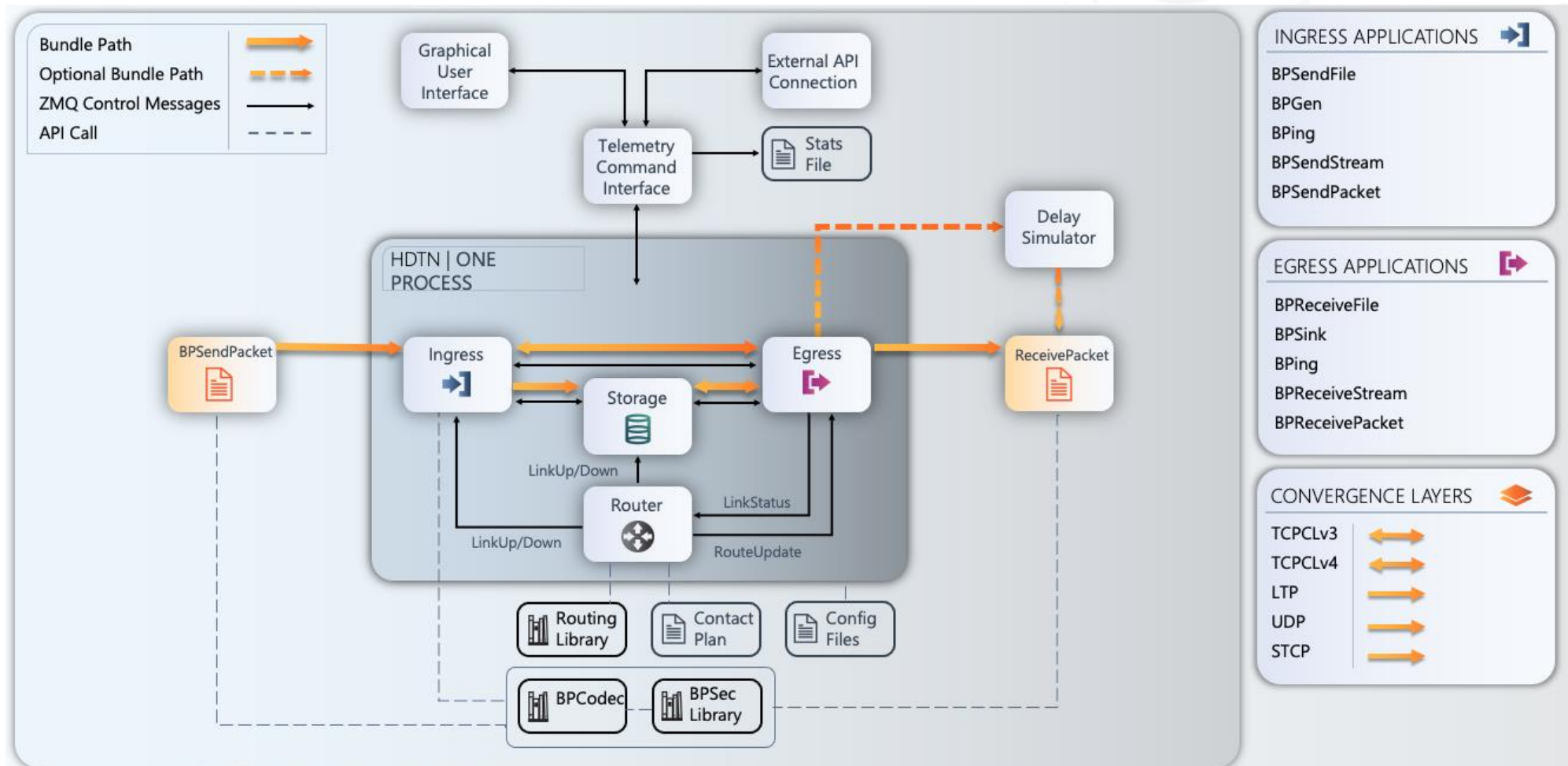
- The internet started with the Arpanet as a resource sharing network, encouraging people collaboration.
- Machine to machine communications- Document sharing and file transfer Applications → Human to human communications- Email and chat Applications
- Building delay/disruption tolerant Applications → make DTN operational and lay the foundation to build a Solar System Internet
- Important design considerations: Interactive/graphical applications; high availability, interoperability, reliability, security



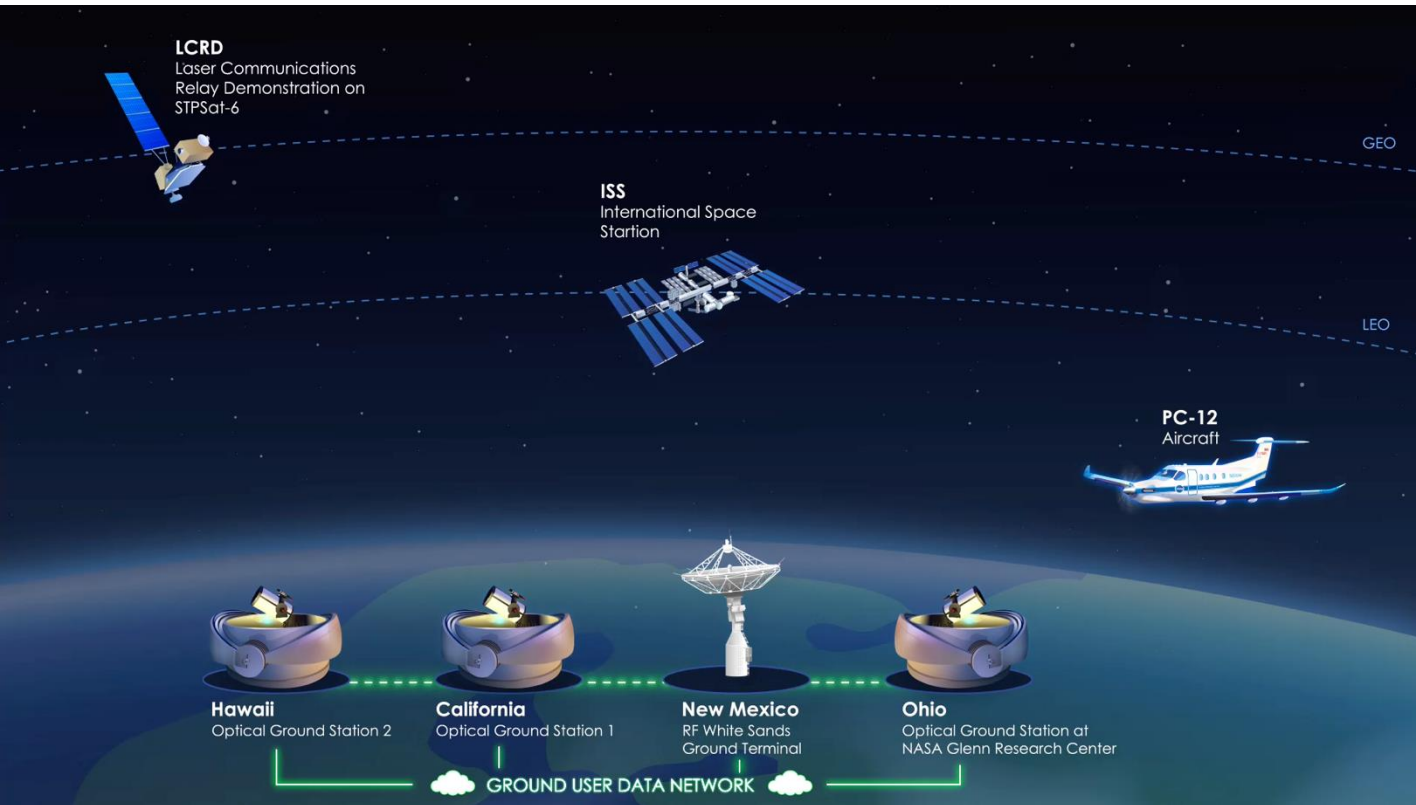
DTN Applications

- Chat
- Voice/Video calls, instant messaging, file sharing
- Email
- File Transfer
- EKG sensor Monitoring

HDTN Architecture



Chat application - ISS flight testing



- There was a need to facilitate communication between HDTN flight and ground operators
- At first communication were handled via text messages and satellite links (Iridium Go App)
 - ⇒ Unreliable: Loss of messages during disconnections , a shared phone number passed around
 - ⇒ A need for a delay tolerant messaging solution

Chat

- ION bpchat : used to communicate with the ground during ISS LCRD/ILLUMA-T flight testing

```
09:44:57, amusic1:/hdtm/home/amusic/ion-open-source-4.1.2/demos/bench-udp/2.bench.udp#./ionstart
[i] admin pgm using SDR parm overrides from bench.ionconfig.
wmKey:          0
wmSize:         50000000
wmAddress:      0
sdrName:        ''
sdrWmSize:      0
configFlags:    1
heapWords:      200000000
heapKey:        -1
logSize:        0
logKey:         -1
pathName:       '/tmp'
Stopping ionadmin.
Stopping ionadmin.
Stopping ionsecadmin.
Stopping ipnadmin.
Stopping bpadmin.
09:45:11, amusic1:/hdtm/home/amusic/ion-open-source-4.1.2/demos/bench-udp/2.bench.udp#bpchat ipn:2.2 ipn:3.2
This is a message from 2.bench.udp
This is a message from 3.bench.udp
Who sent this message?
```

Chat

- HDTNChat: more robust interface, includes timestamp, usernames, BPsec support

```
09:34:00, amusic1:/hdtm/home/amusic/hdtm/hdtmchat_v7#./chatstart.sh
Convergence Layer (ltp, stcp, tcpcl, udp): ltp
Use Security? (y/n) y
Host IP or Hostname: 10.54.31.97
Remote IP or Hostname: 10.54.31.50
Node ID: 1
Host Username: User_1
Remote Username: User_2
Starting HDTNChat using LTP with Security
"10.54.31.97"
"10.54.31.50"
bpgen_config made.
bpsink_config made.
recv_config made.
send_config made.
hdtm_config made.
BPsec configured.
Initializing HDTNchat as Node 1...
Starting HDTNChat HDTN process...
Starting HDTNChat receiver process...
Starting HDTNChat sender process...
HDTNchat: SECURE started as Node 1.
Chat Log Found at logs/hdtmchat_amusic1.hdtm.lan_2024-07-19_09-34-55.log
[User_1] > This is a message from HDTNChat
[13:44:52 UTC][13:36:04 UTC][User_2] > This is a message from User_2 to User_1
[User_1] > 
```

Demo HDTNChat: encrypted messages exchanges during flight testing



Voice/Video calls and instant messaging

qTox: a chat, voice, video, and file transfer IM client using the encrypted peer-to-peer Tox protocol



Instant messaging

Chat instantly across the globe with Tox's secure messages.



Voice

Keep in touch with friends and family using Tox's completely free and encrypted voice calls.



Video

Catch up face to face, over Tox's secure video calls.



Screen sharing

Share your desktop with your friends with Tox's screen sharing.



File sharing

Trade files, with no artificial limits or caps.



Groups

Chat, call, and share video and files with the whole gang in Tox's group chats.

HDTN integration with qTox

- Redirect all outgoing network packets coming from qtox's udp port to bpsendpacket's induct
- Redirect all locally generated network packets destined for bprecvpacket's outduct to qtox's udp port
- Block any additional traffic from qtox

Activities

Firefox Web Browser

orin4

Toxing on qTox

Search Contacts

By Name | All

Groupchat #0

2 users in chat

orin3

Toxing on qTox

Jacob vm

Toxing on qTox

qTox - orin3 (Online)

orin3

Toxing on qTox

2024-08-23

Cleared

08:24:05

Type your message here...

HDTN GUI_X

localhost:8086

60%

System View GUI

Statistics

Config

Ingress Data Rate (Mbps)

0.002

Average Rate

0.008

Max Rate

0.041

Ingress Stats

Ingress Bundle Count Storage 0

Ingress Bundle Count Egress 469289

Ingress Bundle Count 469289

Ingress Bundle Data 104755236.00

Ingress Data Rate

Data Rate (Mbps)

Timestamp (s)

Egress Stats

Egress Message Count 469289

Egress Bundle Count 469287

Egress Bundle Data 104755006.00

Egress Data rate 0.003

Egress Data Rate

Data Rate (Mbps)

Timestamp (s)

Storage Stats

Total Bundles Erased From Storage 0

Total Bundles Sent To Egress From Storage 0

Used Space Bytes 0

Free Space Bytes 81920000000

Bundle Destinations

0%

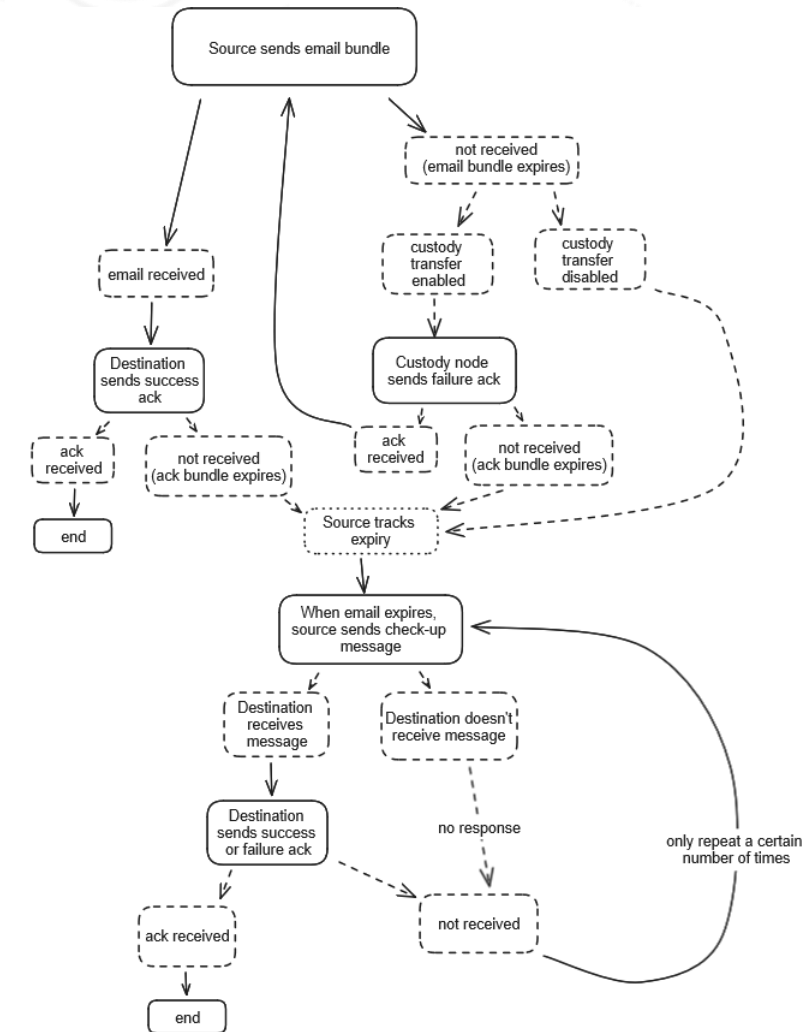
100%

Egress

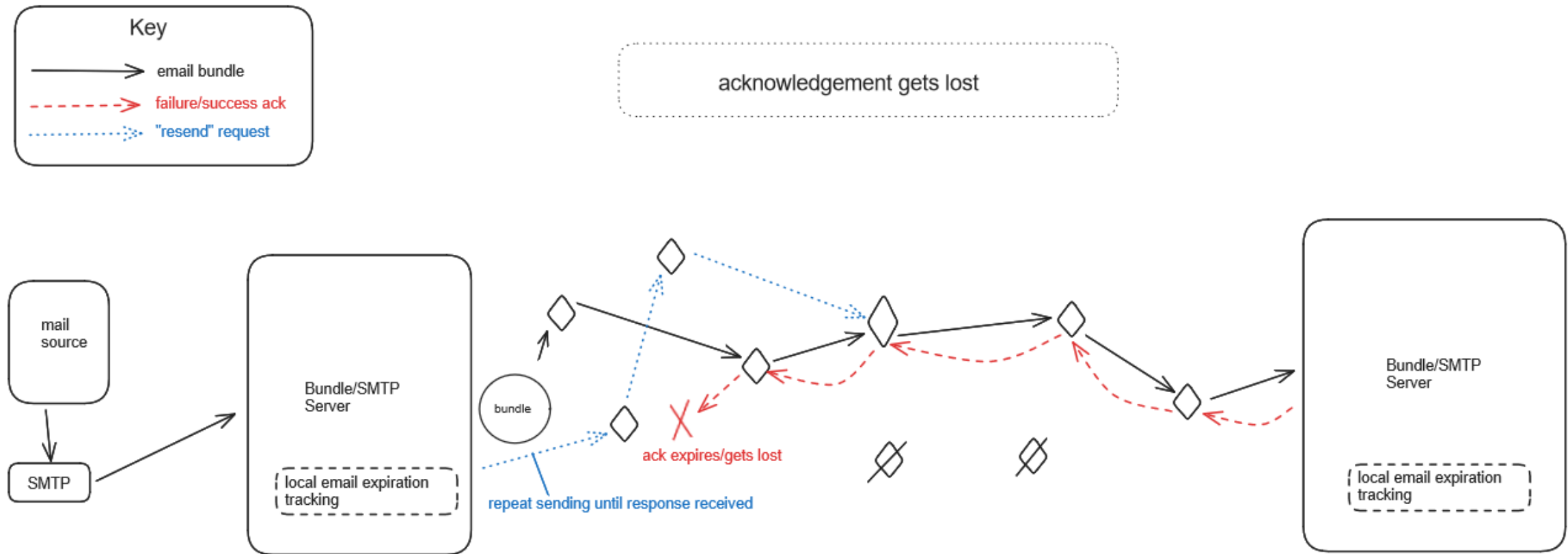
Storage

Email: Design considerations

- Existing email protocols: SMTP/POP3
- Current Mail Transfer Agents (MTA) like Postfix require intercepting email and not made to support DTN by default; Need a separate mail delivery and submission agent → make our own all in one server that supports DTN
- Improving reliability using acknowledgements and acknowledging acknowledgements → Checkup system



Checkpoint System Diagram



Implementation

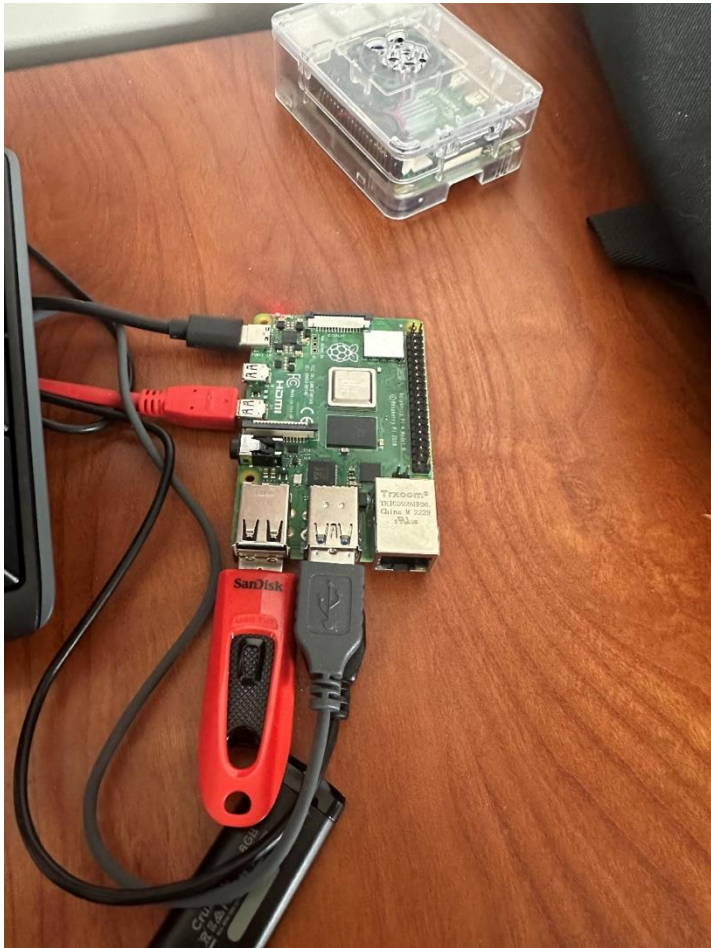
1. Using BPSendPacket instead of creating a custom BPSendEmail
2. SMTP Server
3. Checkup System
4. POP3 Server
5. Logging
6. DNS support
7. End to End Encryption support (BPSend/receivePacket supports BPSec)

```
95 [ hdtm      ][ info ]: LtpUdpEngine batch sender back to normal operation
96 [          ][ info ]: starting..
97 [          ][ info ]: BpSec enabled. Using config file: "/home/hdtm/email/bpsec_flight/email/flight-testing/ruby2/config_files/
sinkbpsec_con_plus_int.json"
```

```
ID:1722870754.8966038/100.1/0 (509 bytes)
```

```
[          ][ info ]: first time ACCEPTED/DECRYPTED a bundle successfully from source node ipn: 102.1 ..(This message type will now be suppressed.)
[          ][ info ]: first time ACCEPTED a bundle's integrity successfully from source node ipn: 102.1 ..(This message type will now be suppressed.)
```

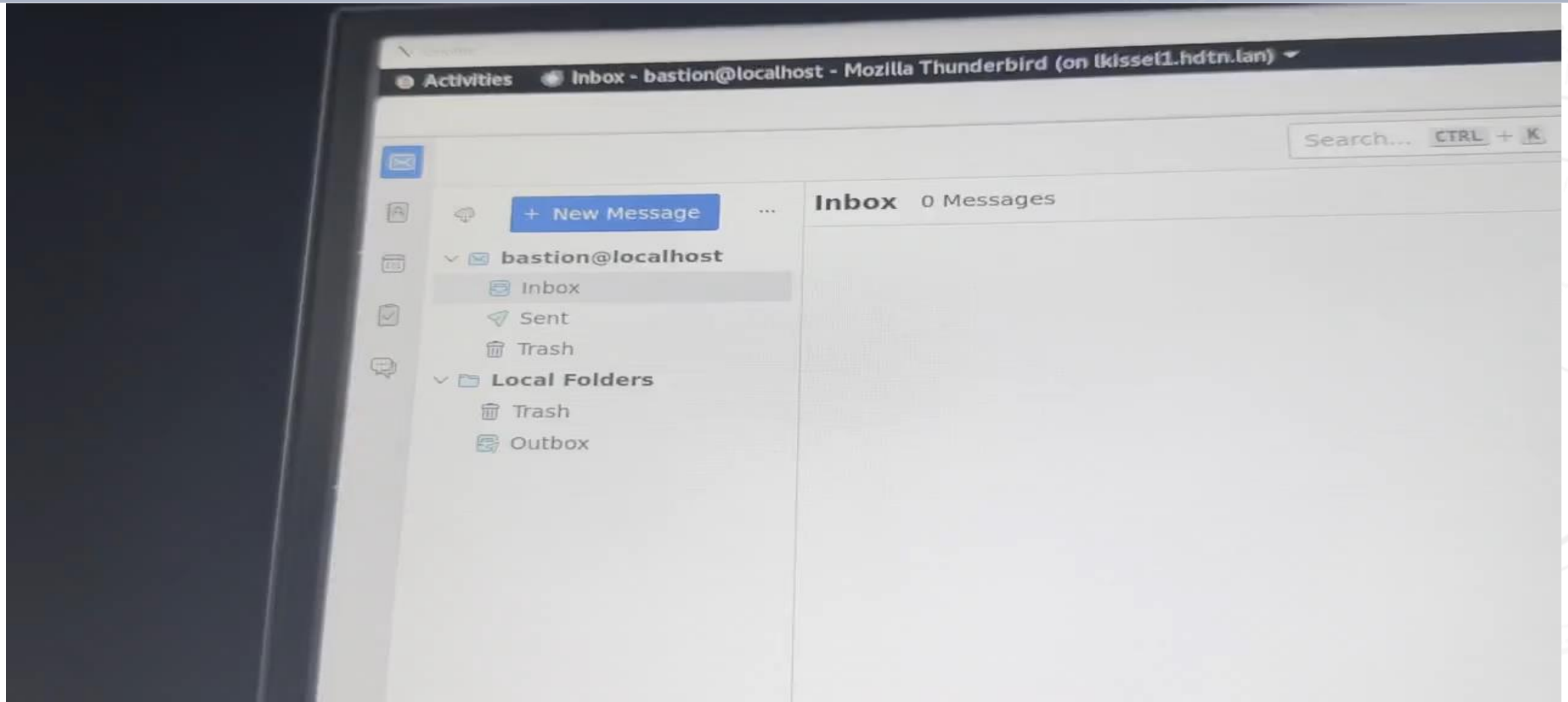
Testing in the lab



Raspberry Pi used for lab testing

- Testing one server support
- Testing multiple servers support (DNS resolution)
- Testing end to End encryption

Demo: Email delivery to only one server



Demo: Email delivery to 2 different servers (DNS resolution)

The screenshot shows a multi-window environment demonstrating email delivery. The windows include:

- Thunderbird Email Client:** A window titled "bastion@bastion.email.nasa.gov" showing an email composition or viewing interface.
- Terminal 1 (kisselpi@kisselpi):** Shows the command `./runprocess.sh 2.1` being executed in the `~/emailtest/nodeTwo` directory.
- Terminal 2 (ubuntu@ubuntu-desktop):** Shows the command `./runprocess.sh 3.1` being executed in the `~/email/nodeThree` directory. The output includes:

```
(venv) ubuntu@ubuntu-desktop:~/email/nodeThree$ ./runprocess.sh 3.1
BPsec configured.
Starting HDTN...
HDTN One Process Started
Starting BPReceivePacket...
BPReceivePacket Started
Starting BPSPendPacket...
BPSPendPacket Started
Node Started!
Starting SMTP Server...
[INFO] (SMTP) Logging started!
[INFO] (POP3) Ready.
```
- Terminal 3 (kisselpi@kisselpi):** Shows the output of the script, including a message about sending emails over POP3 and a confirmation that the email was sent successfully.
- Terminal 4 (kisselpi@kisselpi):** Shows the output of the script, including a message about sending emails over POP3 and a confirmation that the email was sent successfully.

Demo: End to end encrypted email delivery

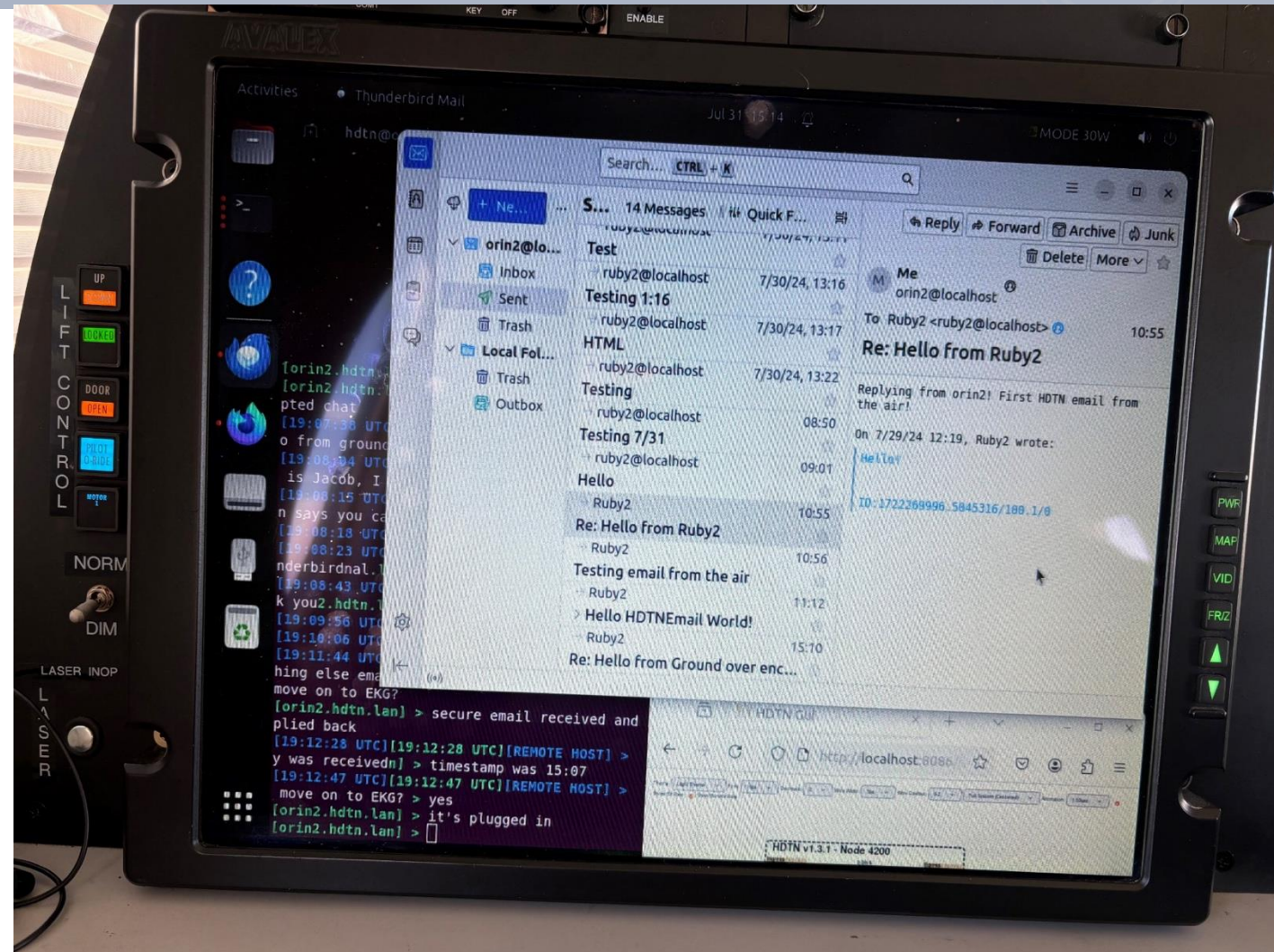
The image displays a demo of end-to-end encrypted email delivery, showing three main components:

- Thunderbird 'Write' Window:** A window titled "Write: (no subject) - Thunderbird (on kissel1.hdtm.lan)". It shows the email composition interface with fields for "To" (Bastion M. Kissel <bastion@bastion.e... bastion@bastion.email.nasa.gov>) and "Cc" (Bcc). The "Format" menu is open, showing options like "OpenPGP", "Spelling", "Save", and "Contacts".
- Thunderbird 'Inbox' Window:** A window titled "Inbox - pi@kisselpi.email.nasa.gov - Mozilla Thunderbird (on kisselpi)". It shows the email inbox with a search bar and a list of folders: "Inbox", "Sent", "Trash", "Local Folders", "Trash", and "Outbox". The status bar indicates "Inbox 0 Messages".
- Terminal Window:** A terminal window showing the execution of a script. The output includes logs for "BPsec configured", "Starting HDTN...", "HDTN One Process Started", "Starting BPreceivePacket...", "BPreceivePacket Started", "Starting BPSendPacket...", "BPSendPacket Started", "Starting BPSendPacket 2...", "BPSendPacket 2 Started", "Node Started!", "Starting SMTP Server...", "[INFO] (SMTP) Logging started!", "[INFO] (POP3) Ready.", "[INFO] (POP3) Subthread server created", "[INFO] (POP3) Subthread connected to and ready", "[DEBUG] (POP3) COMMAND: b'CAPA', ARGS: None", "[DEBUG] (POP3) COMMAND: b'USER', ARGS: [b'bastion@bastion.email.nasa.gov']", "[DEBUG] (POP3) COMMAND: b'PASS', ARGS: [b'password']", "[DEBUG] (POP3) Subthread authenticated", "[DEBUG] (POP3) COMMAND: b'STAT', ARGS: None", "[DEBUG] (POP3) COMMAND: b'QUIT', ARGS: None", and "[DEBUG] (POP3) Mailbox emails at the moment of QUIT command: []".

Flight testing



Flight testing results and Demo





File transfer

- Currently HDTN uses command line to send files using BPsendFile and BPRceiveFile Applications
- There's a need for a new User Interface to show the progress status of a file transfer:
 1. Added another tab for file transfer to HDTN version 2 GUI
 2. Developed using React and Next.js
 3. Imported a table to display the file name, size and progress of the transfer
 4. Imported a function that allows you to track the progress of the file transfer

Results

Activities Firefox Aug 7 14:20

Developer Tools — HDTN — http://localhost:8087/filetransfer

HDTN

localhost:8087/filetransfer 150%

Import bookmarks... Oracle Linux Home Oracle Linux Support Oracle Linux Blog Unbreakable Linux Net... Linux Technology Center Oracle Linux Downloads Oracle Linux Training Oracle Linux Forum Source Technologies

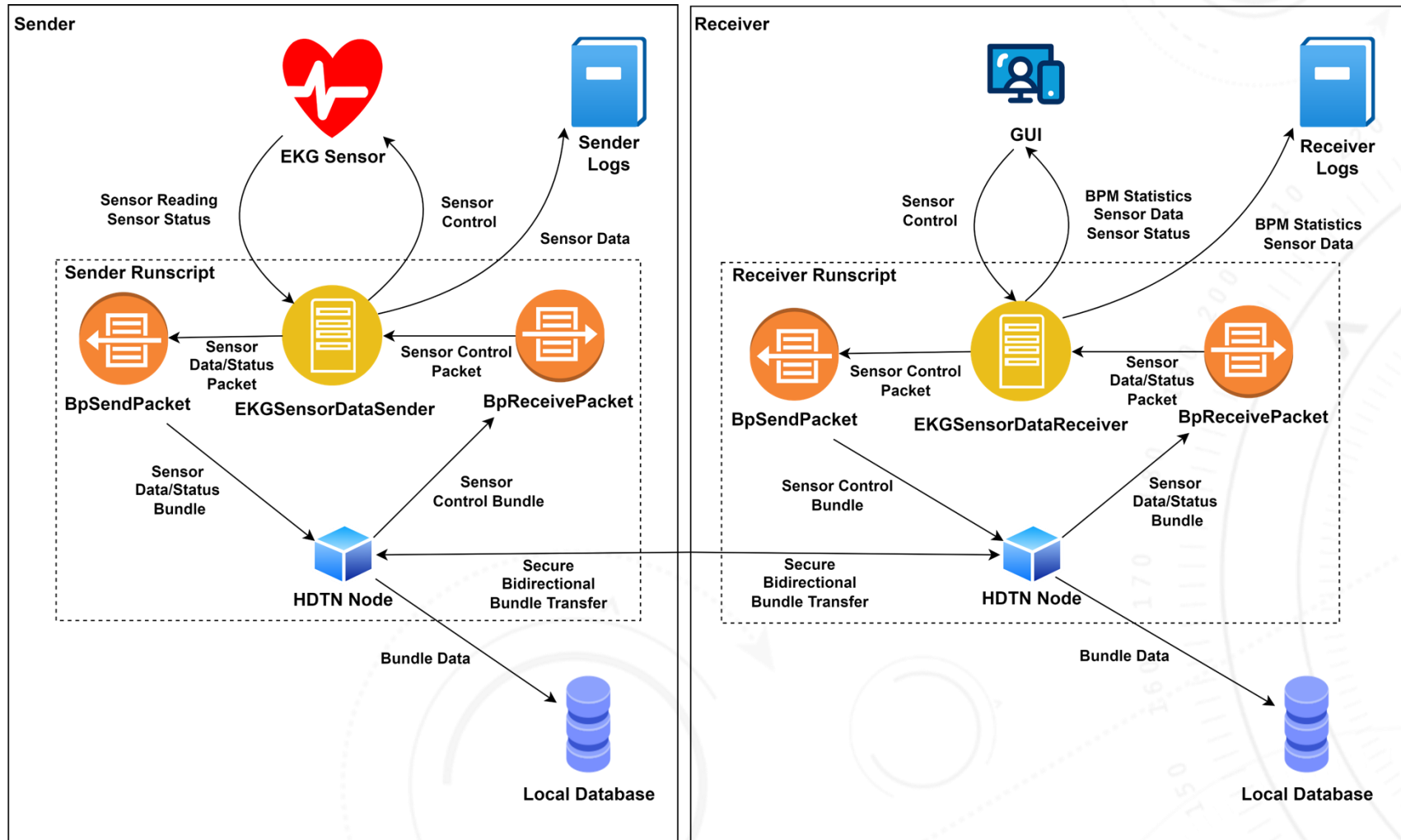
HOME CONFIGURATION FILE TRANSFER

File Name	File Size	Progress
Screenshot.png	74205 Bytes	

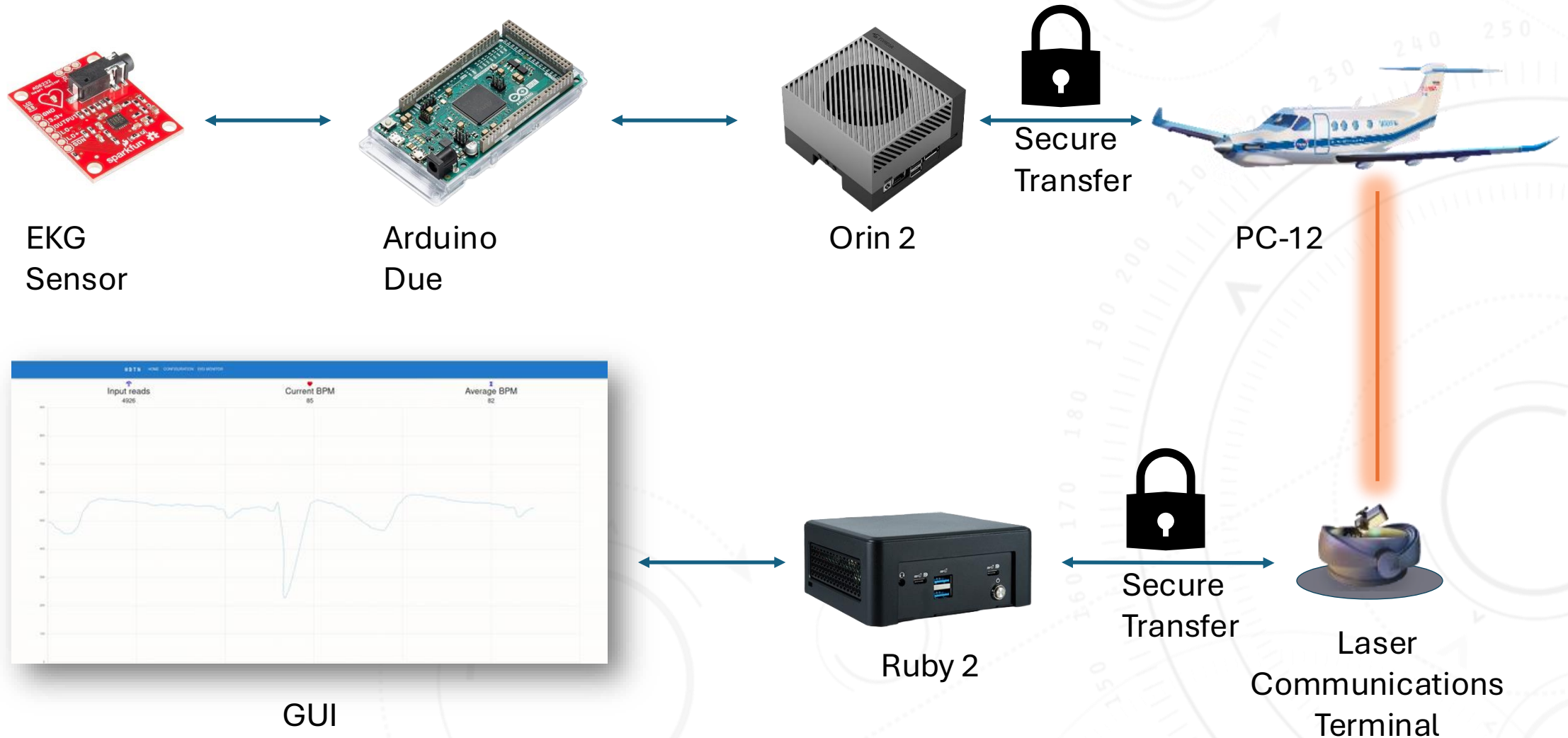
EKG Sensor Monitoring

- Application that securely transmits biometric data and sensitive health information
- Exercise the command-and-control IoT capability of HDTN with high priority data
- Real-time monitoring of passenger vitals through Graphical User Interface
- framework for deep-space sensor overlay, with bidirectional communication
- Relation control infrastructure will enable real-time monitoring of systems, with ability to act against operational issues

Software Architecture



Flight Testing Topology





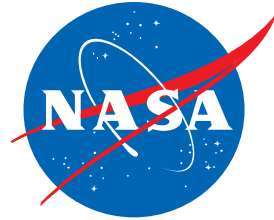
Flight testing results

- Bidirectional data pipeline, capable of securely sending over **600** sensor readings per second
- IoT command-and-control capability over HDTN
- Successfully accomplished real-time EKG monitoring over HDTN between PC-12 and ground station through GUI
- Efficiently transported data with an average of **0.1%** packet loss

Impact

A futuristic space scene. In the foreground, an astronaut in a white spacesuit stands on a dark, rocky lunar surface, looking towards a massive, glowing blue network of lines that arches across the sky. The network consists of numerous bright blue nodes connected by thin, glowing lines, creating a complex web. In the background, the Earth is visible as a blue and white sphere, surrounded by a similar network of lines. A small satellite with solar panels is in orbit around the Earth. The overall atmosphere is one of advanced technology and space exploration.

- **Real-time health monitoring for Artemis astronauts**
- **Remote sensor tuning to adjust for environmental changes**
- **Up-to-date status messages, allowing for faster command center action**



nadia.kortas@nasa.gov