National Aeronautics and Space Administration

DTN Applications

IEEE Workshop on OptimizingInterplanetary
Communication Through Network Autonomy
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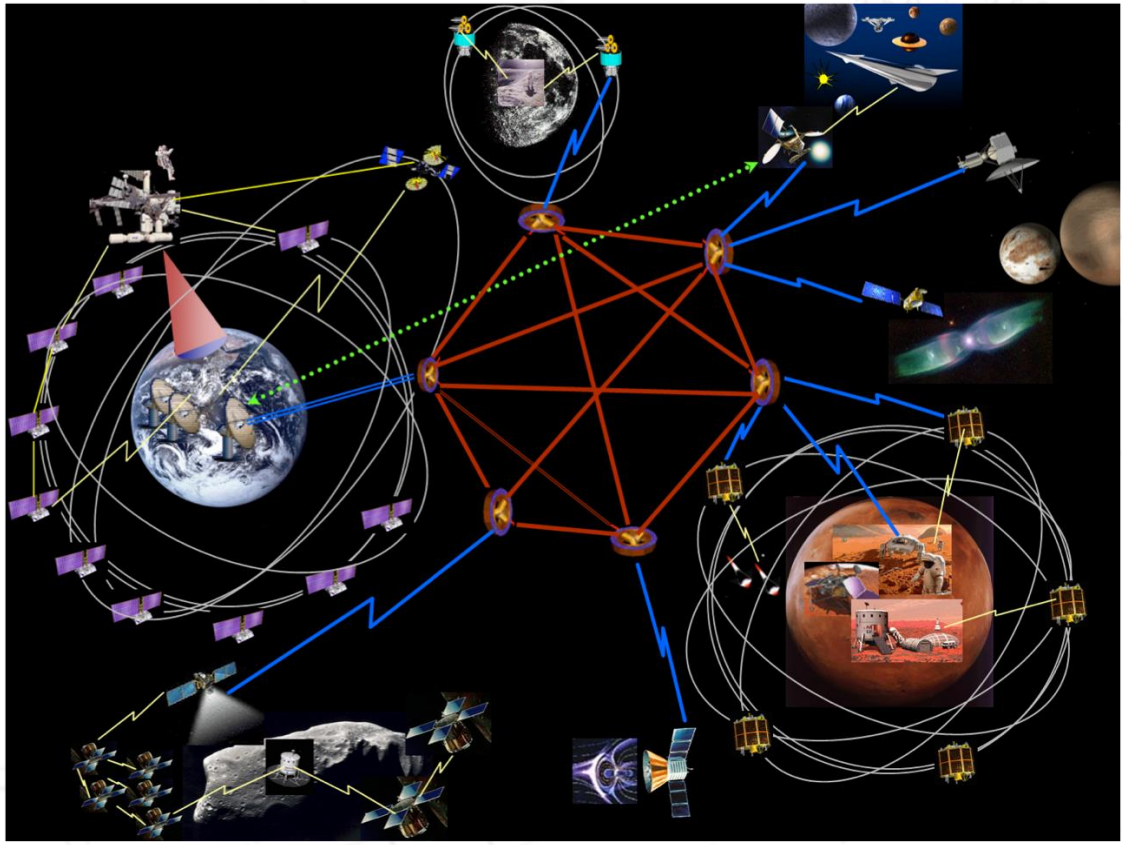
Solar System Internet

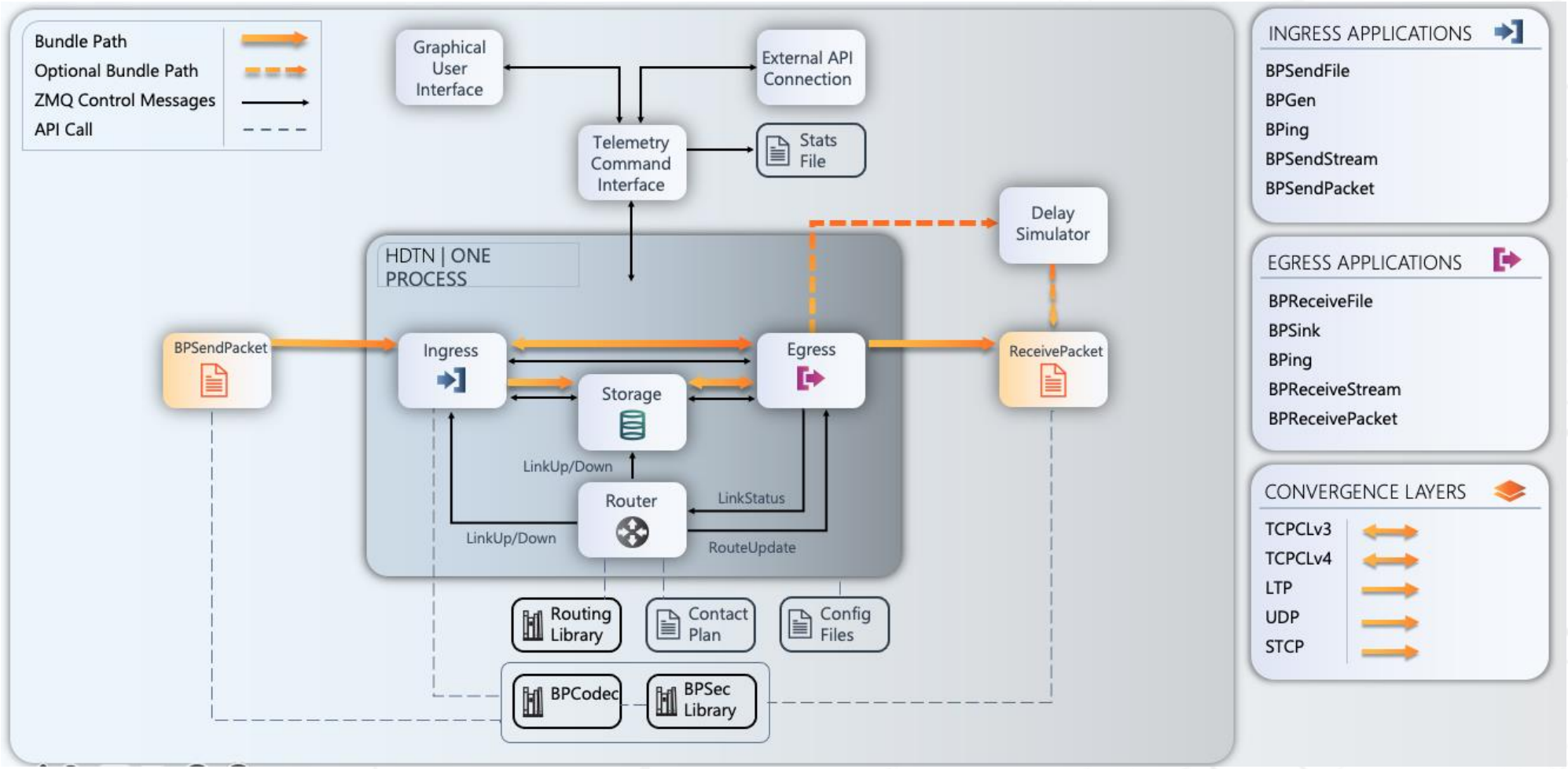
- The internet started with the Arpanet as a resource sharing network, encouraging people collaboration.
- Machine to machine communications- Document sharing and file transfer Applications ➔ Human to human communications- Email and chat Applications
- Building delay/disruption tolerant Applications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



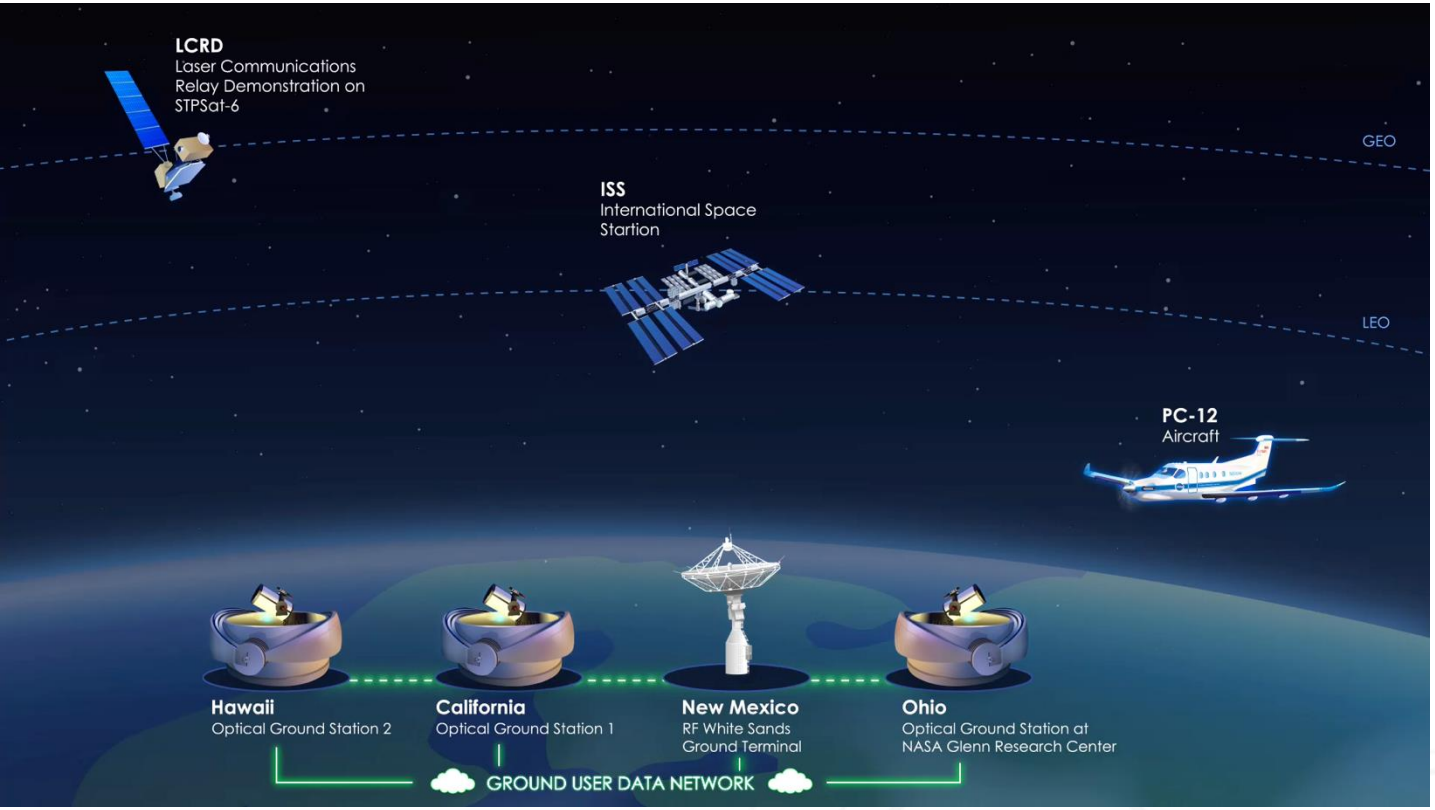
DTN Applications

- 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:/hdtn/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:      20000000
heapKey:        -1
logSize:        0
logKey:         -1
pathName:       '/tmp'
Stopping ionadmin.
Stopping ionadmin.
Stopping ionsecadmin.
Stopping ipnadmin.
Stopping bpadmin.
09:45:11,amusic1:/hdtn/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:/hdtn/home/amusic/hdtn/hdtnchat_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.
hdtn_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/hdtnchat_amusic1.hdtn.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

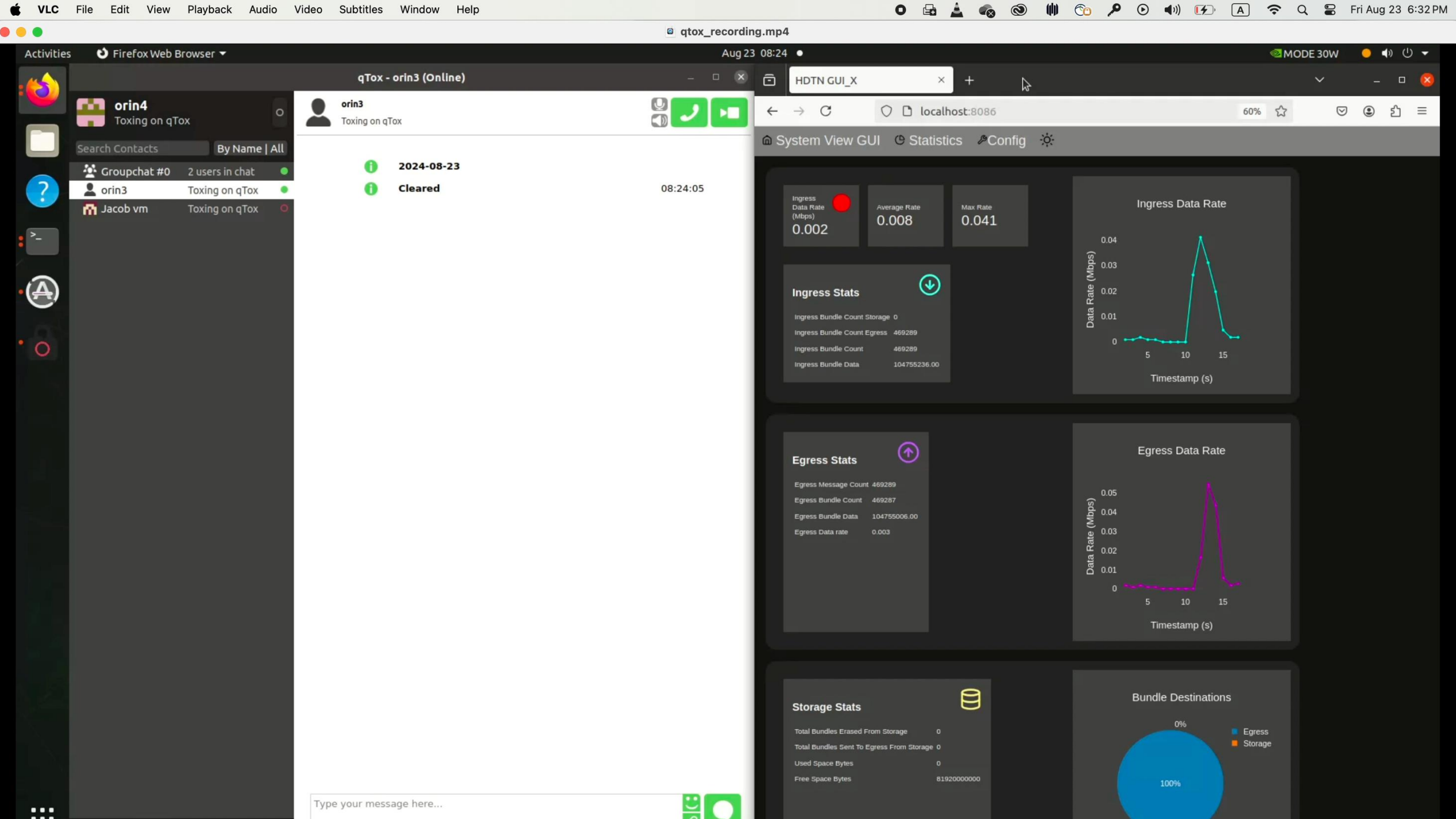
Trade files, with no artificial limits or caps.

Groups

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

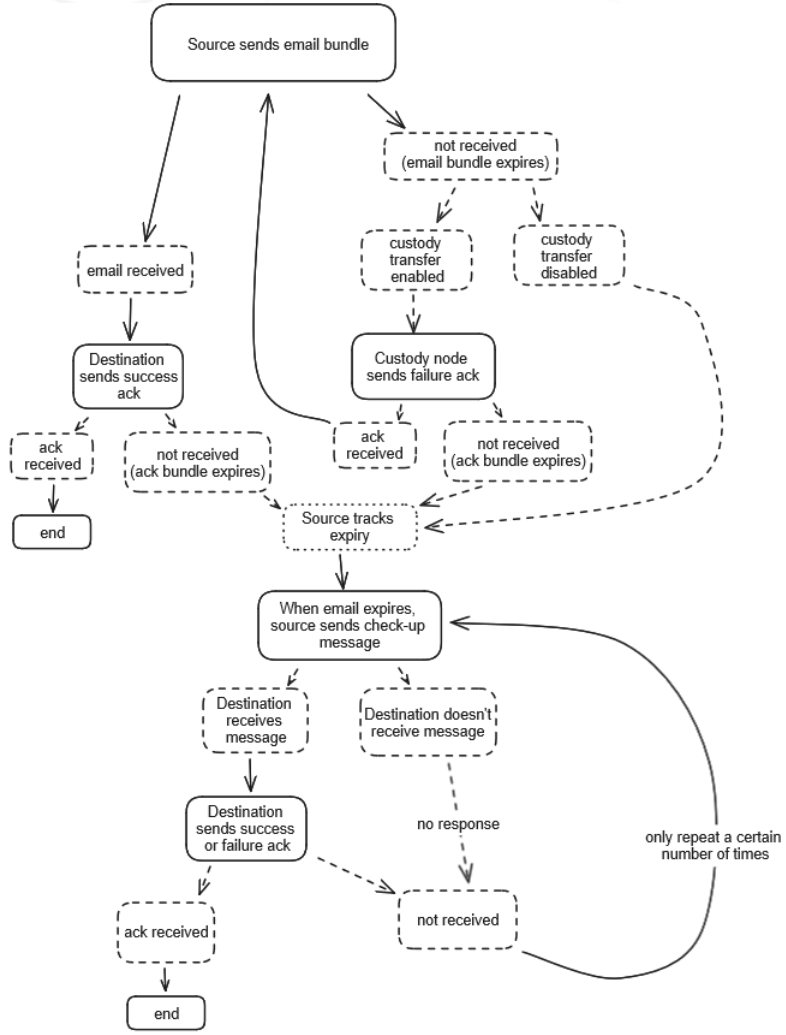
HDTN integration with qTox

- 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

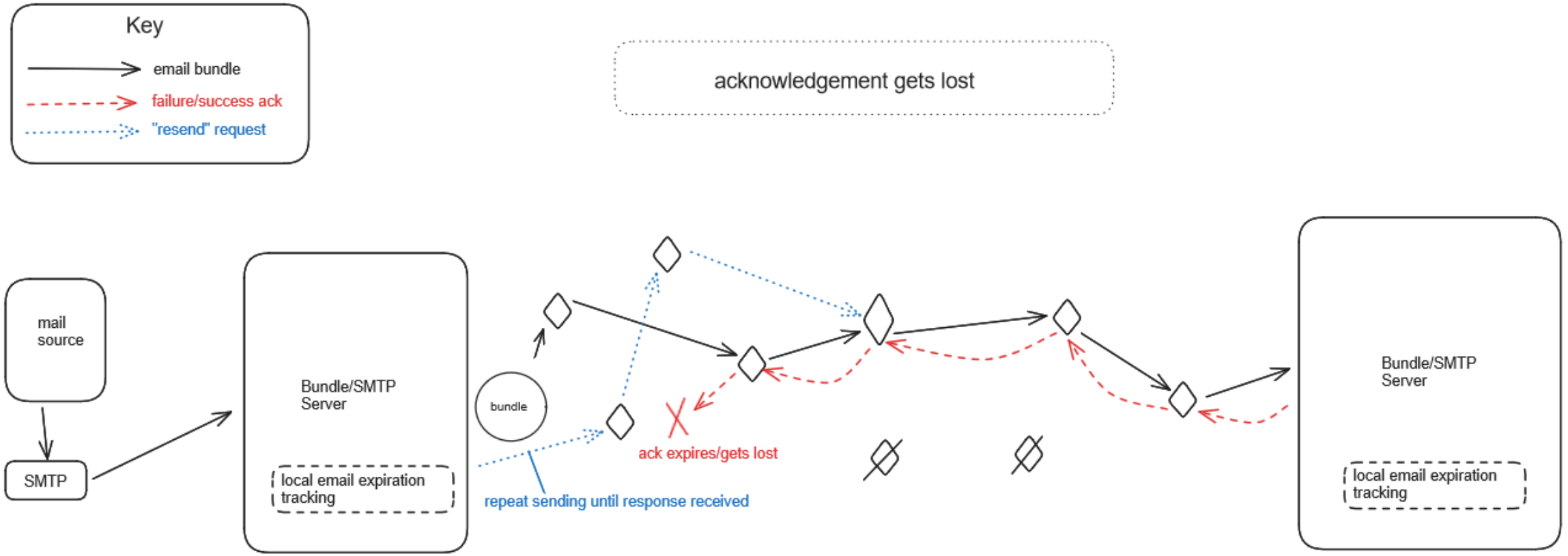

VLC File Edit View Playback Audio Video Subtitles Window Help
Fri Aug 23 6:32 PM
qtox_recording.mp4
Activities
Firefox Web Browser
Aug 23 08:24
MODE 30W
qTox - orin3 (Online)
orin4
Toxing on qTox
Search Contacts
By Name | All
Groupchat #0 2 users in chat
orin3 Toxing on qTox
Jacob vm Toxing on qTox
orin3
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
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



Checkup System Diagram



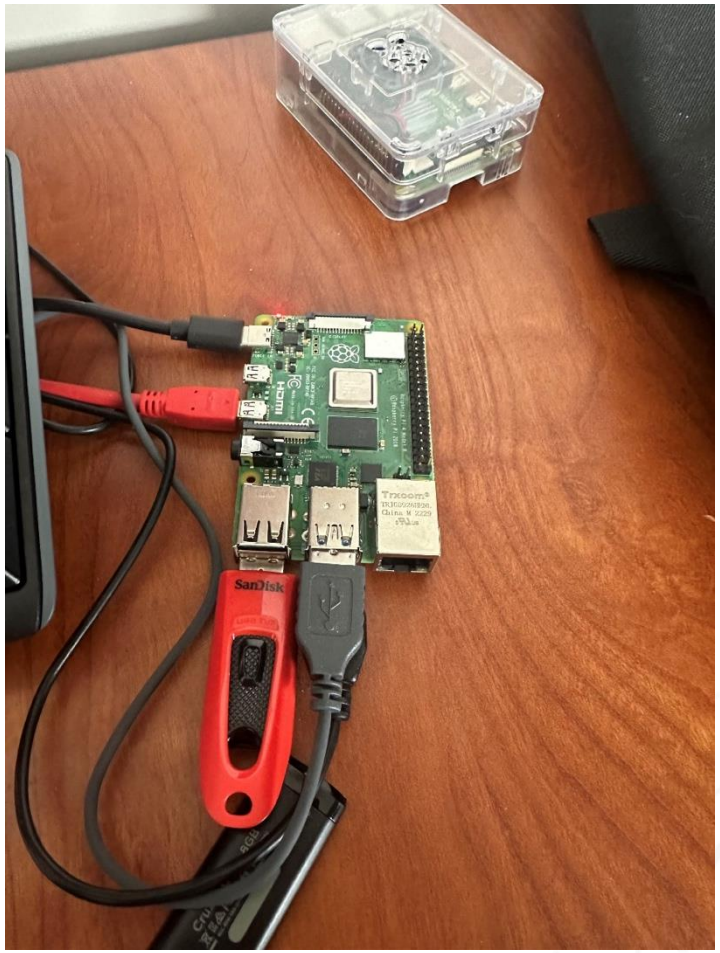
Implementation

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 [ hdtn     ][ info ]: LtpUdpEngine batch sender back to normal operation
96 [          ][ info ]: starting..
97 [          ][ info ]: BpSec enabled.  Using config file: "/home/hdtn/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.)
```

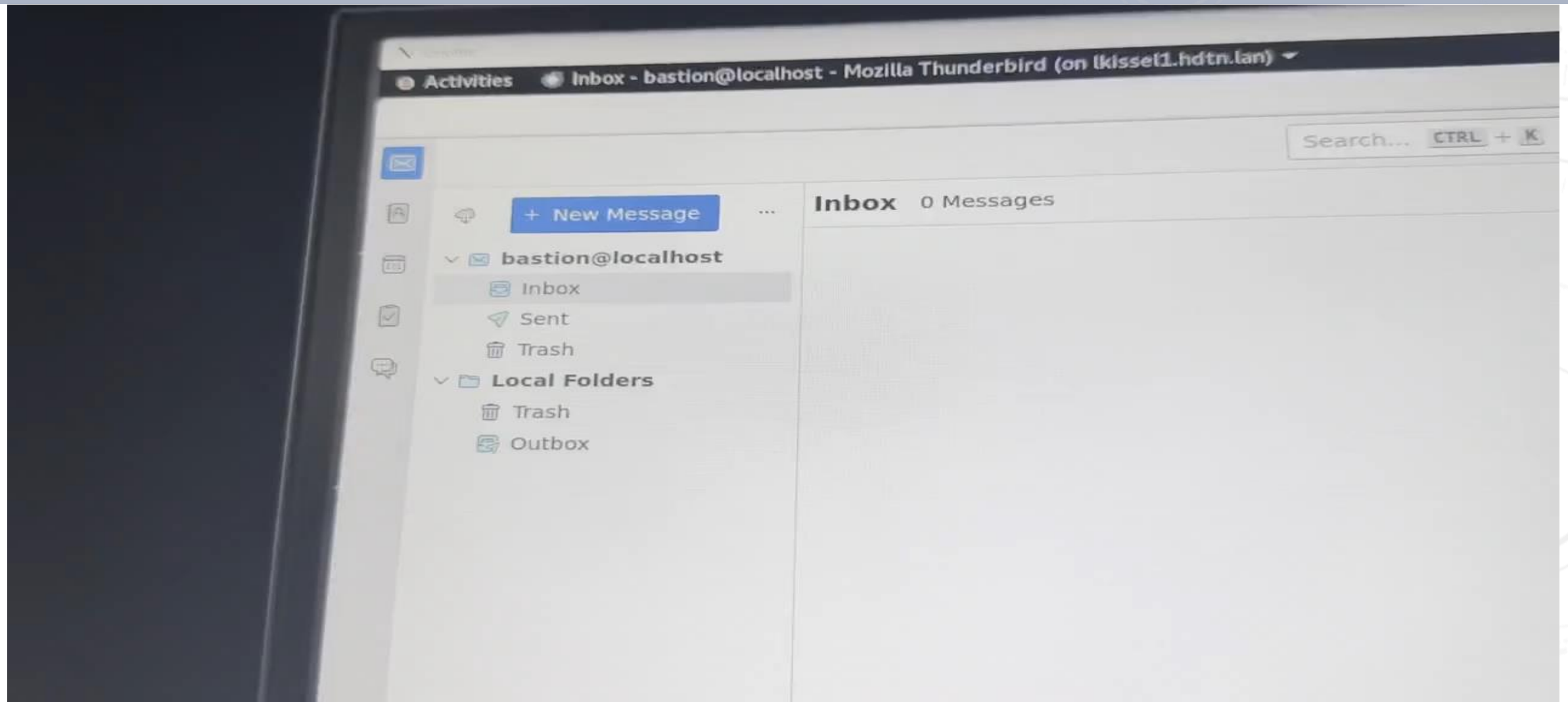
Testing in the lab



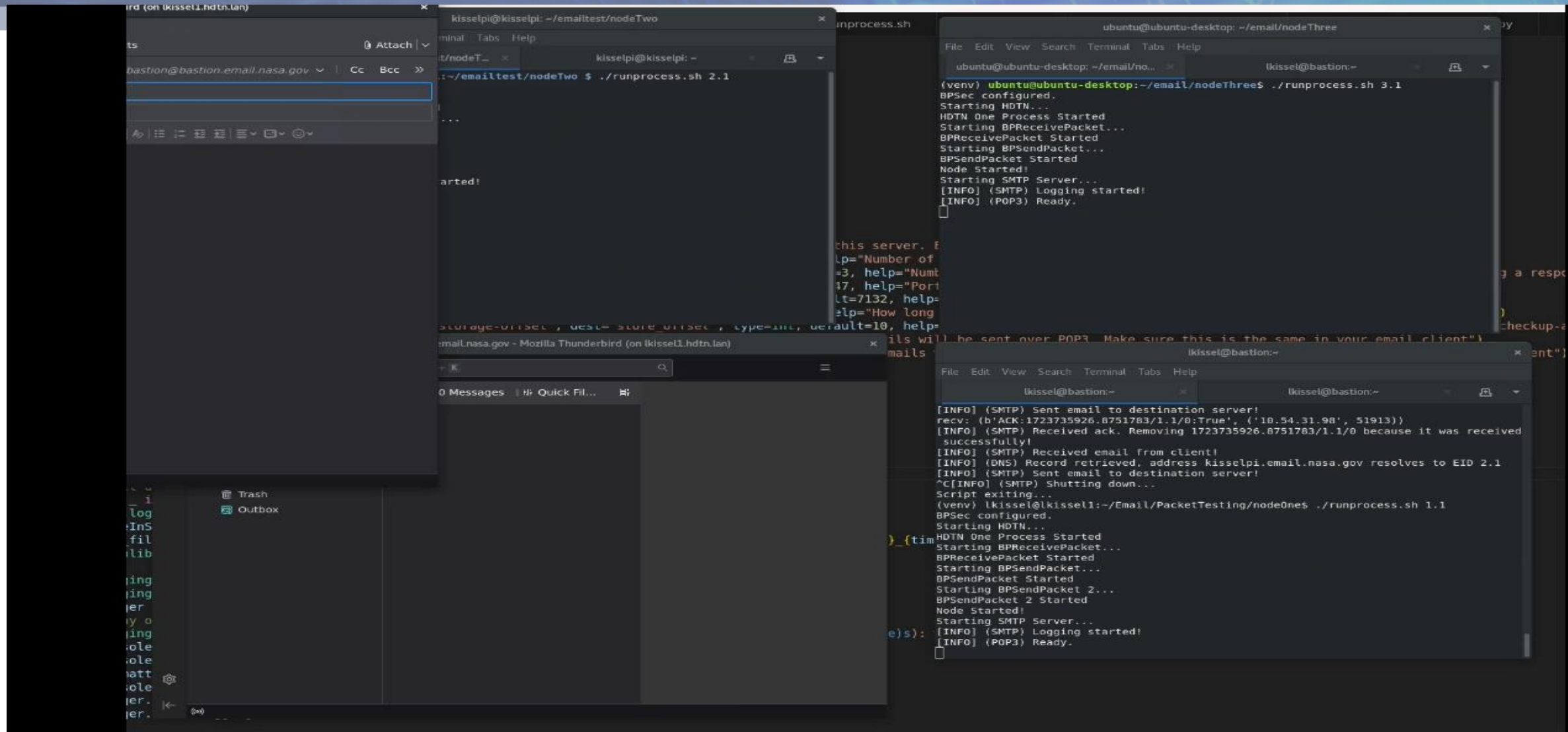
Raspberry Pi used for lab testing

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

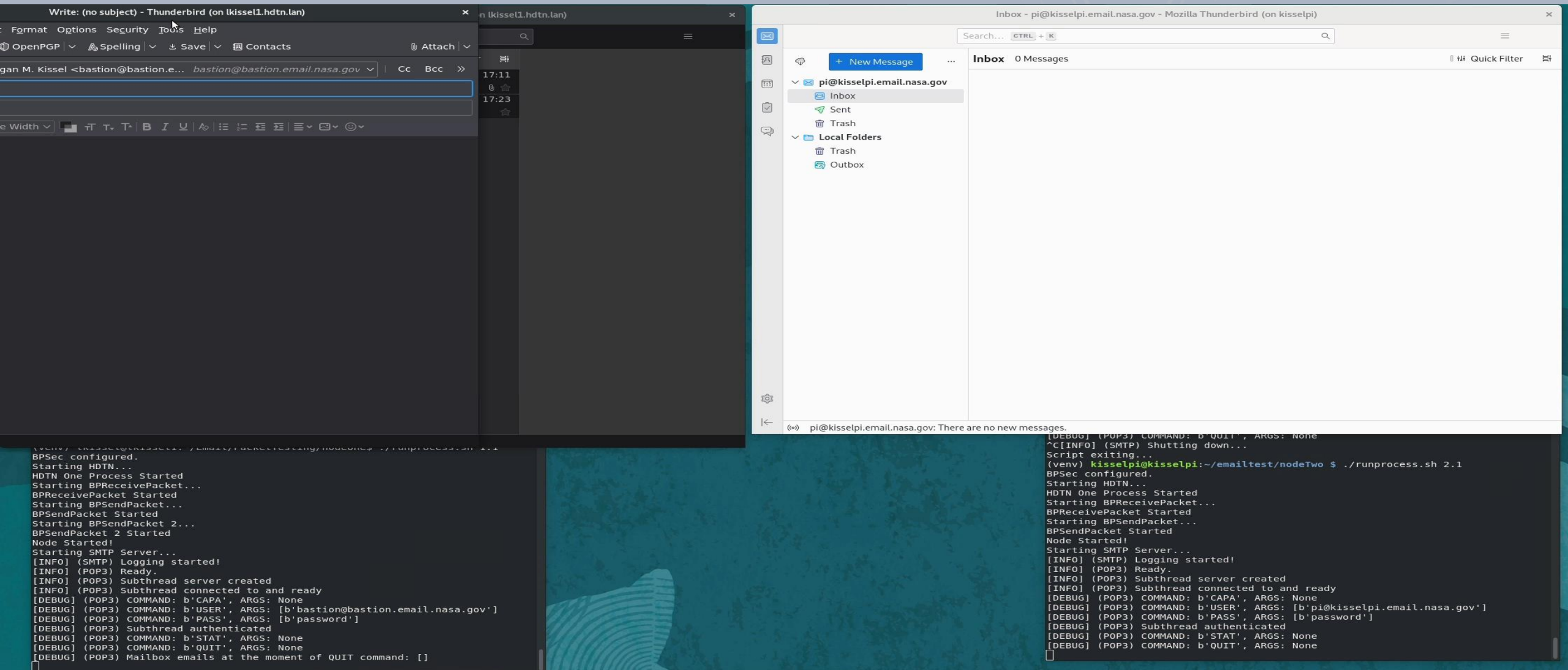
Demo: Email delivery to only one server



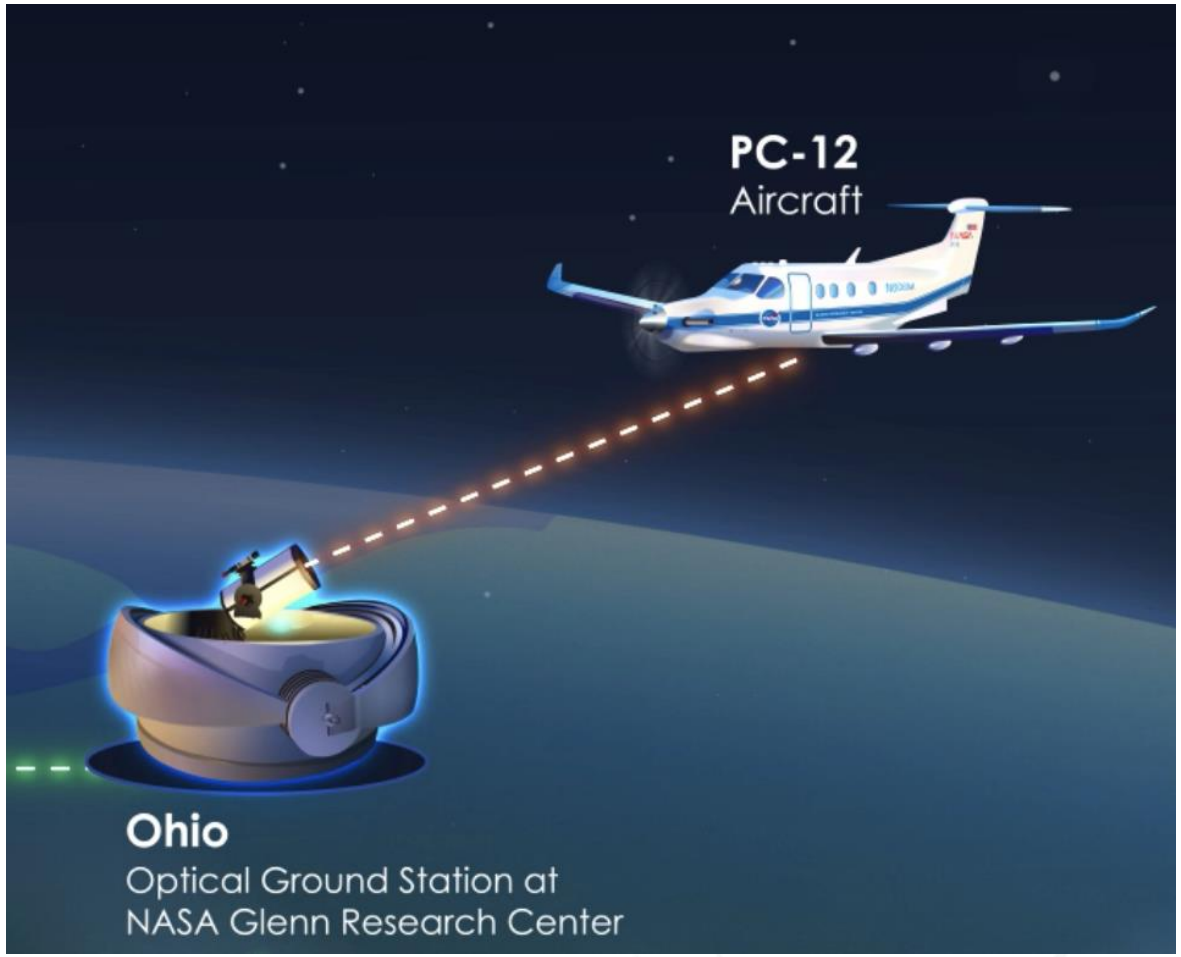
Demo: Email delivery to 2 different servers (DNS resolution)



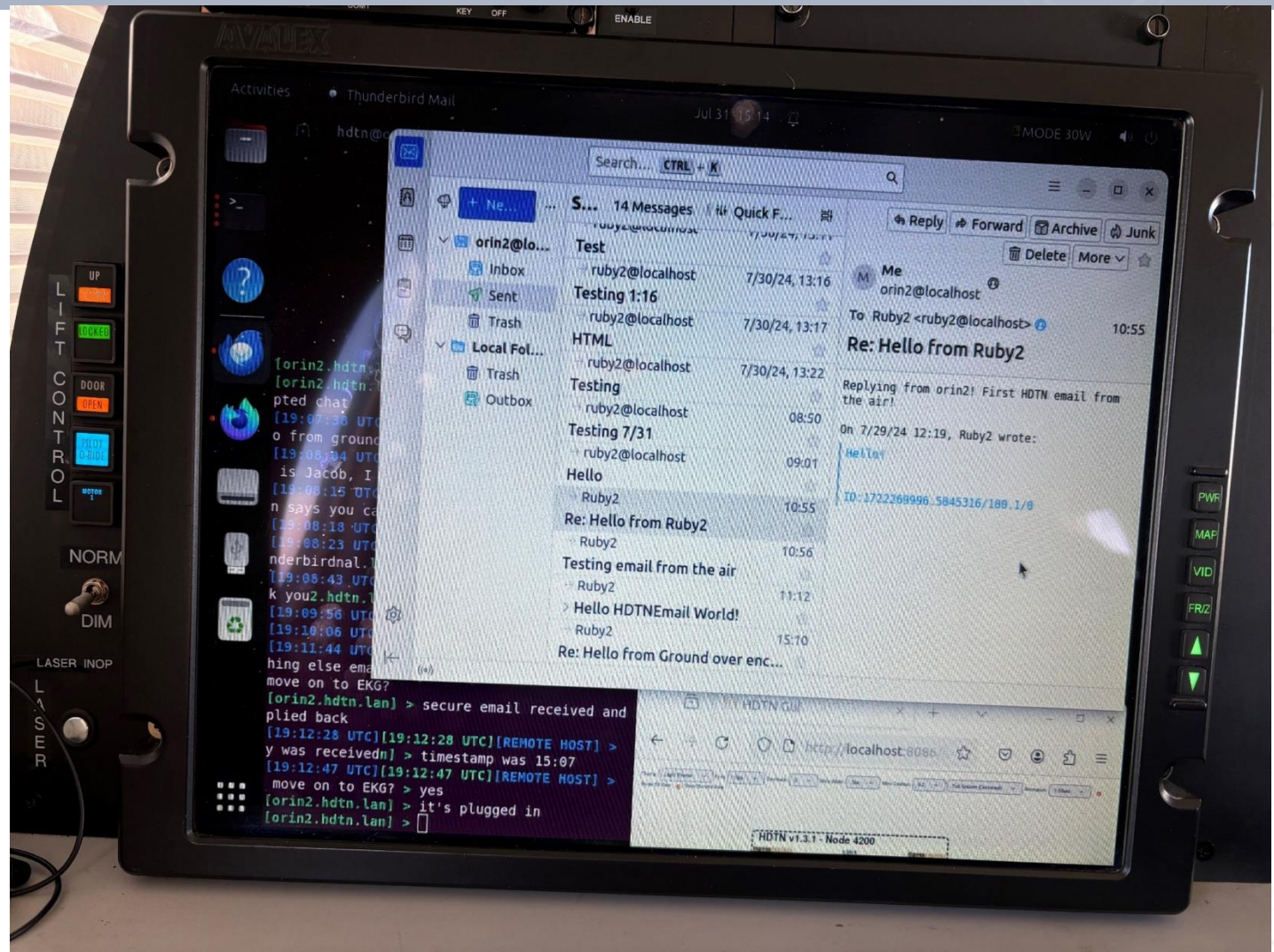
Demo: End to end encrypted email delivery



Flight testing



Flight testing results and Demo

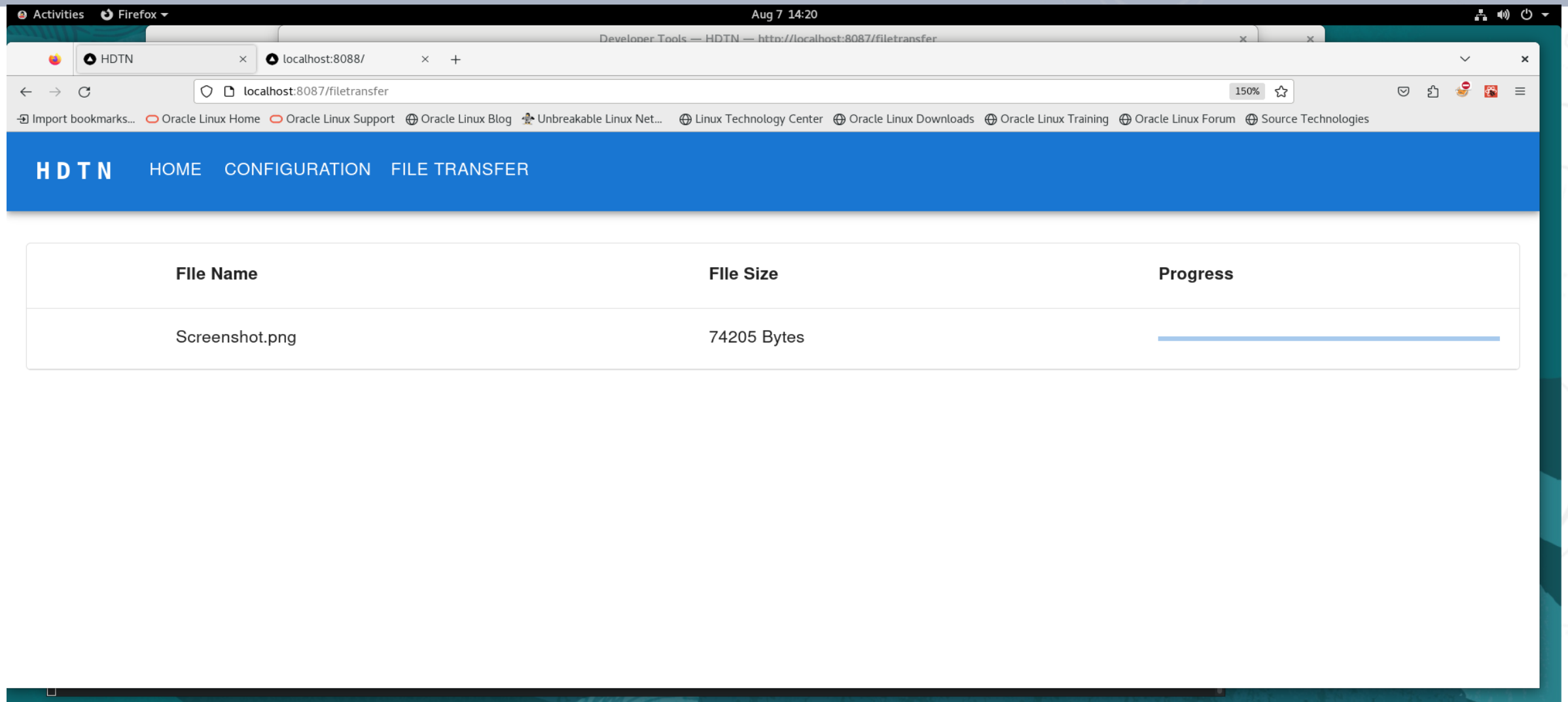


File transfer

- Currently HDTN uses command line to send files using BPsendFile and BPReceiveFile 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

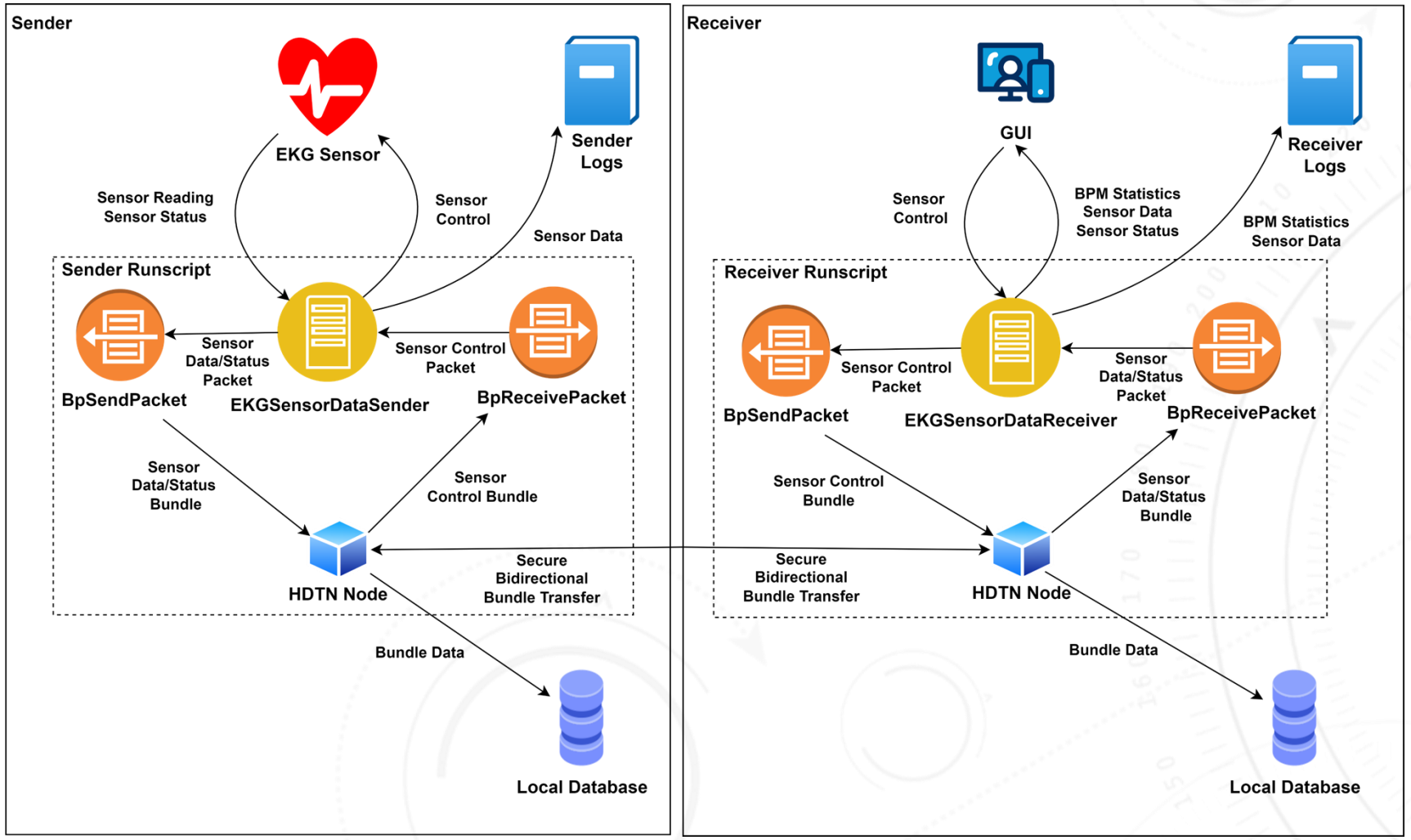
Results


Activities
Firefox
Aug 7 14:20
HDTN
localhost:8088/
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
HDTN
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

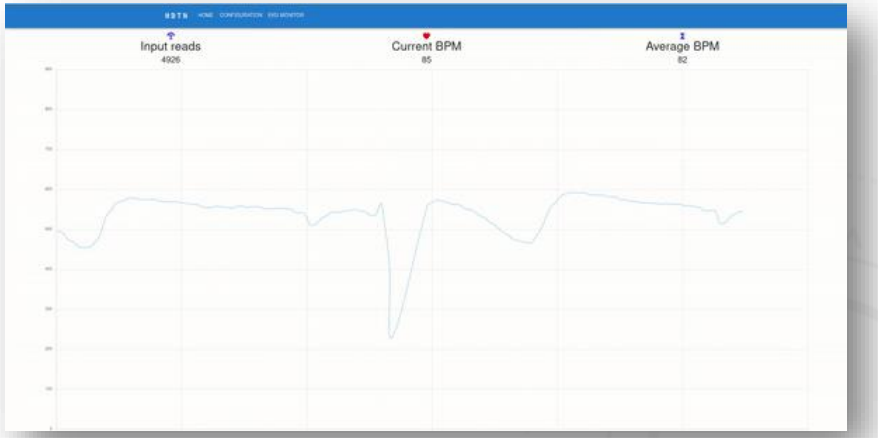
EKG Sensor

Arduino Due

Orin 2

Secure Transfer

PC-12

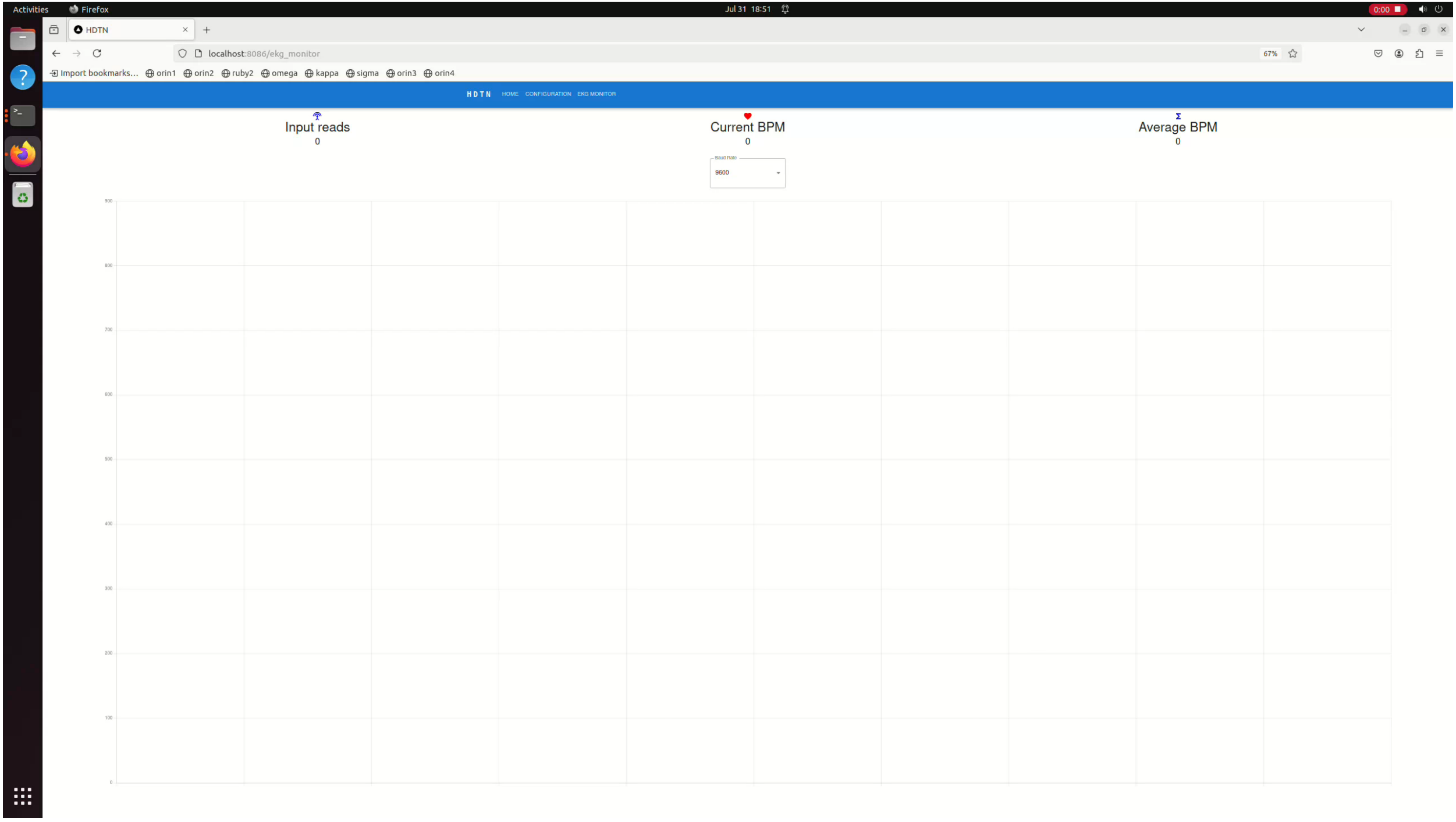


GUI

Ruby 2

Secure Transfer

Laser Communications Terminal


Activities
Firefox
Jul 31 18:51
0:00
HDTN
localhost:8086/ekg_monitor
67%
Import bookmarks...
orin1
orin2
ruby2
omega
kappa
sigma
orin3
orin4
HDTN
HOME
CONFIGURATION
EKG MONITOR
Input reads
0
Current BPM
0
Average BPM
0
Baud Rate
9600
900
800
700
600
500
400
300
200
100
0

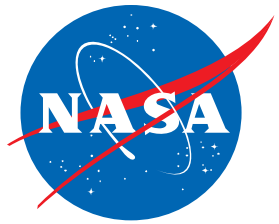

NO SMOKING

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

- 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



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