Efficient Network Coding for Satellite Applications: A Live Demo of HENCSAT and NECTOR

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Abstract—**Satellite communication is available anywhere on earth, allowing connectivity to systems like Unmanned Aerial Vehicles (UAV) in very remote geographical areas. However, satellite airtime is expensive, and a reduction of the amount of transmitted data can lead to significant cost savings. The goal of the Highly-Efficient Network Coding for Satellite Applications (HENCSAT) project is to reduce such costs by using our approach Network Coding with Torrents (NECTOR). NECTOR combines network coding, Torrent-based transmission, and H.265 highly efficient video encoding. In our demonstration, we would like to showcase NECTOR in an interactive HENCSAT test bench setup.**[1][2][3]

Keywords: Unmanned Aerial Vehicles, Satellite Communications, Network Coding, HENCSAT, NECTOR, Live Demo

I. INTRODUCTION

The operation of Unmanned Aerial Vehicles (UAV) can significantly reduce the costs of search and rescue operations as well as inspections in remote geographical areas. For example, the Norwegian coast guard must be able to search for castaways in case of accidents on remote oil rigs in the Arctic Sea. Operating helicopters and rescue ships in such an environment, with rough weather conditions, is time-consuming and expensive. Another example is to inspect remote pipelines or power lines in the Australian outback, like the Nullarbor, with almost no infrastructure like roads or airstrips. Professional UAVs can operate over long distances and for long durations, avoiding the need for unnecessary transport of equipment, tucker and personnel into remote areas. This greatly reduces the overall costs. Control of UAVs is made via satellite communications, which is available anywhere on earth, with appropriate Service Level Agreements (SLA). However, satellite airtime is expensive as well. For example, INMARSAT has service plans ranging from 70 USD to 6500 USD for limited data usage with additional 3 USD to 5 USD per MiB for extra usage. So, reducing the communication over satellite can lead to further significant cost savings.

The goal of the Highly-Efficient Network Coding for Satellite Applications (HENCSAT) project [1] is to reduce the communication costs of the not-flight-relevant data and video transmission. First, in the use case scenarios, some delay is tolerable. For example, in our use cases where it may take hours to send a rescue ship or a helicopter with a repair team, there is the possibility to increase video compression by generating larger chunks, called videograms (VGRAM), of e.g. one 30 s to 120 s duration. Furthermore, the resolution and frame rate of the video stream can be reduced, and relevant details requested on demand only by the control centre. Secondly, while satellite communication is available anywhere on earth, an UAV may also be in reach of 3G/4G/5G mobile broadband networks during period of its flight, e.g. while being close to the populated coast line of Norway, or nearby a roadhouse in the Nullarbor.

Our solution Network Coding with Torrents (NECTOR) [1] reduces the video transmission costs by combining:

- Network Coding (NC) [2], [3],
- Torrent-based [4] transmission over multiple network (e.g. satellite network and 2 reachable mobile broadband operators), and
- H.265 [5] highly-efficient video encoding for VGRAMs.

In the HENCSAT test bench, we have deployed NECTOR in a setup with emulated networks and the possibility to interactively adjust the characteristics of these underlying networks. We already used this test bench to evaluate NECTOR [1] and compare it to simple streaming solutions [6] based on Multi-Path TCP (MPTCP) [7]. It is shown in [1] that our solution performs better and achieves significantly lower transmission costs. In our proposed demo, we would like to showcase NECTOR to the audience with an interactive live demo in the HENCSAT test bench.

II. NECTOR

NECTOR [1] is a comprehensive multipath networking solution without the need for scheduling, rate-adaptation or forward error correction algorithms. Figure 1 presents the data units and protocol stack for the NECTOR. It is an Application Layer protocol where the Application Layer is further divided into several sub-layers specific to the NECTOR protocol.

First, the video stream, also referred as data stream, is segmented into small files. We refer to these files as videogram (VGRAM) for video or datagram (DGRAM) in general for any data stream. VGRAMs are further divided in multiple chunks. Since the sender and the receiver are connected via multiple networks, the receiver request these

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[3] The authors would like to thank the anonymous reviewers for their helpful comments.

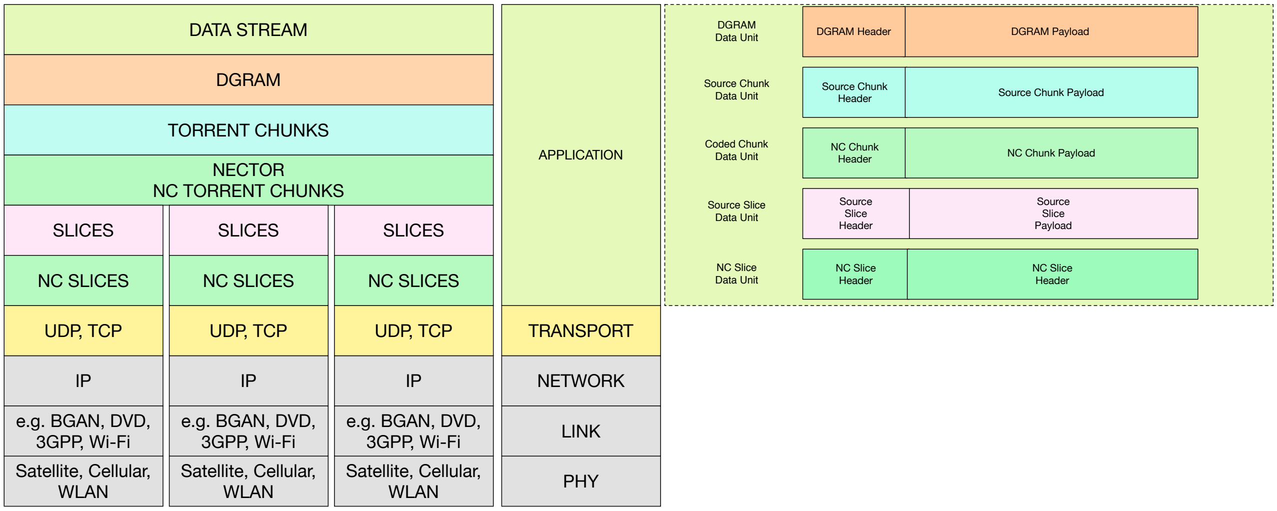


Fig. 1. NECTOR Protocol Stack

chunks from the sender via multiple networks. To avoid the need of tracking and scheduling a specific chunk to one of the multiple networks available, we use network coding to encode the chunks and then we transfer the coded chunks via available networks. Each chunk carries one degree-of-freedom, i.e., if K_s source chunks are encoded together then K_s coded chunks are required to obtain the original K_s source chunks. The network coding at chunk level facilitates the scheduling of chunks via multiple networks without the need to design any complex scheduler. Once the receiver receives the chunks from one of the available networks, it simply requests another chunk and so on.

Secondly, the chunks are further divided into slices, and these slices are sent over the User Datagram Protocol (UDP). We use a second layer of network coding for slices to provide protection against the packet losses. In this case, we use network coding as a forward erasure correction code, where the coded packets are used to recover the lost packets. The network coding rate is adaptive, and it is being selected based on the feedback of packet losses. For example, if a measured packet loss ratio is p, then the code rate $\rho > p$ is selected. In this case, if K_s is the number of source slices, then $N_s > \frac{K_s}{\rho}$ coded slices are sent. The network coding rate may differ per network, since these are independent connections with independent packet loss ratios. To deploy the NECTOR protocol, we defined and implemented the different protocol units with their specific header and payload structures as shown in Figure 1.

III. THE HENCSAT TESTBED

Figure 2 provides an illustration of our HENCSAT test bench: PC 1 is an embedded, x86_64-based PC, which could also be installed on an UAV. It is hosting the VGRAM video sender (live camera or recorded video), which uses a NECTOR Sender for transmission. The routers, implemented by small Odroid XU4 ARM64-based embedded systems, are used to emulate the QoS characteristics of underlying networks, e.g. satellite, 3G, 4G, Wi-Fi, etc., with settings for bandwidth, latency, loss rate and error rate for each transmission direction. These QoS characteristics can be interactively adjusted via a GUI. It would furthermore be possible to physically disconnect/reconnect them. Of course, it also would be possible to replace them by real satellite, mobile broadband and/or Wi-Fi equipment. PC 2 is another embedded x86_64-based PC, representing the control centre. It acts as the NECTOR receiver. It provides the received VGRAMs to the VGRAM player GUI for playback. This player GUI can also be used to interactively adjust the parameters of the VGRAMs, e.g. the VGRAM duration, target data rate, resolution, etc.

IV. DEMONSTRATION SCENARIO AND SETUP

Figure 3 presents a screenshot of the NECTOR/HENCSAT GUI running on PC 2. Attendees can interact with the demonstration by using GUI settings to change network parameters including bandwidth, delay and losses to observe the impact of the varying network conditions on the video quality. Additionally, attendees can also switch between different presets of 3G/4G/SatCom network parameters. With the preset configurations, attendees can see that NECTOR adapts and schedules data through multiple networks based on their configured parameters.

The required equipment for the demonstration contains a laptop and a computer monitor. The laptop is used to allow attendees the interaction with the demonstration using the “HENCSAT-QoS-Controller” panel. On the additional monitor, we display the video with the “VGRAM Player”. This video is sent from the VGRAM sender via multiple networks with the settings configured by the attendees. It is received by the VGRAM receiver and we show the received video with the help of “VGRAM Player”. The attendees can also inspect other video-related information, such as sequence number, timestamps, video resolution, bitrate, VGRAM size, etc.

V. CONCLUSIONS

The goal of the Highly-Efficient Network Coding for Satellite Applications (HENCSAT) project and Network Coding

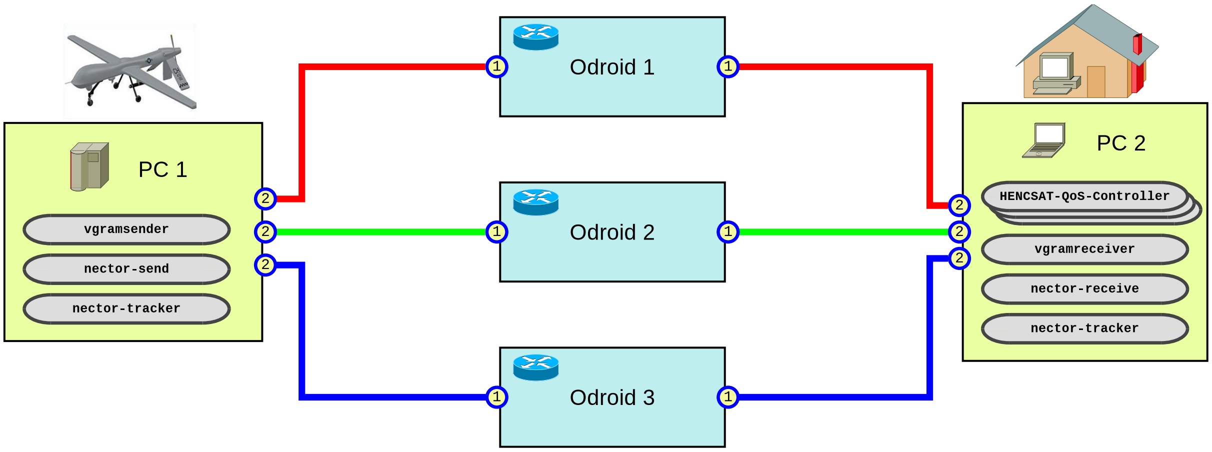
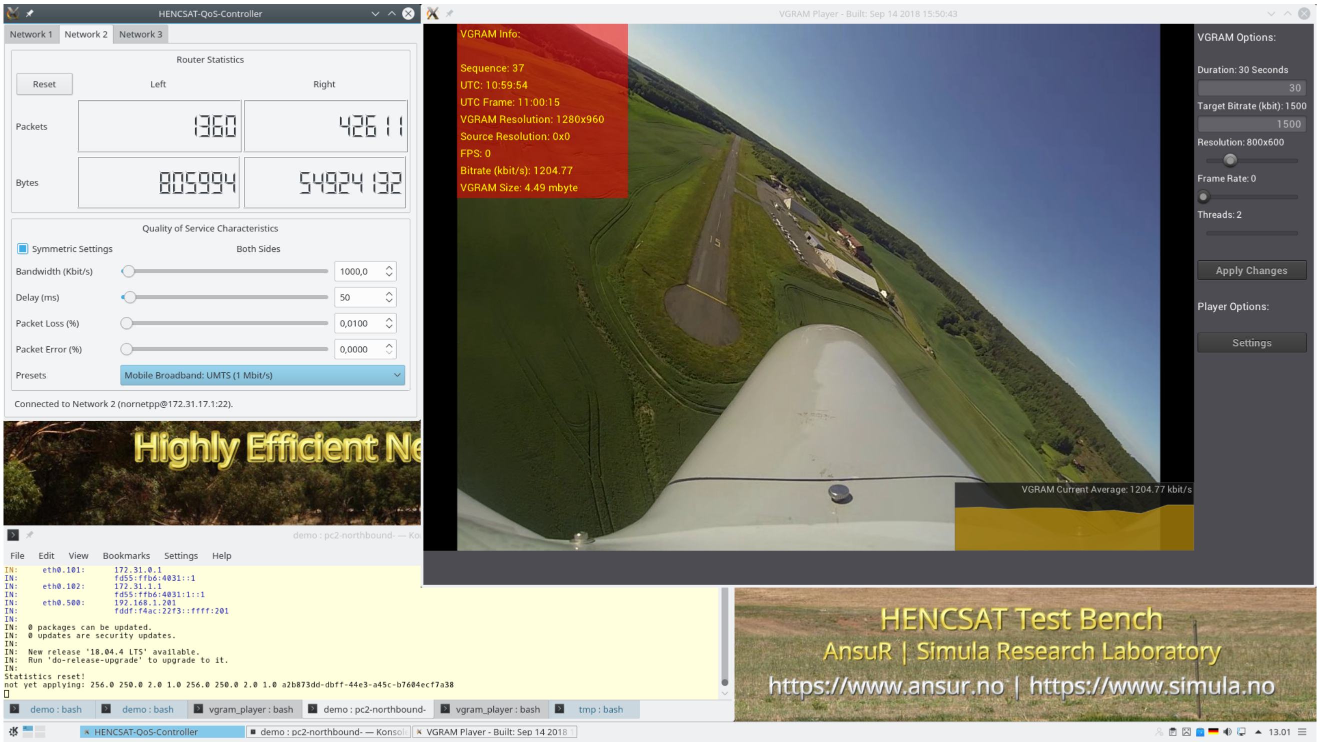


Fig. 2. The HENCSAT Testbed



	Left	Right
Packets	1360	42611
Bytes	805994	54924132

Quality of Service Characteristics

☑ Symmetric Settings — Both Sides

Bandwidth (Kbit/s): 1000,0

Delay (ms): 50

Packet Loss (%): 0,0100

Packet Error (%): 0,0000

Presets: Mobile Broadband: UMTS (1 Mbit/s)

Connected to Network 2 (nornetpp@172.31.17.1:22).

VGRAM Info:

Sequence: 37
UTC: 10:59:54
UTC Frame: 11:00:15
VGRAM Resolution: 1280x960
Source Resolution: 0x0
FPS: 0
Bitrate (kbit/s): 1204.77
VGRAM Size: 4.49 mbyte

VGRAM Current Average: 1204.77 kbit/s

VGRAM Options:

Duration: 30 Seconds — 30
Target Bitrate (kbit): 1500 — 1500
Resolution: 800x600
Frame Rate: 0
Threads: 2

```
IN:     eth0.101:      172.31.0.1
IN:                    fd55:ffb6:4031::1
IN:     eth0.102:      172.31.1.1
IN:                    fd55:ffb6:4031:1::1
IN:     eth0.500:      192.168.1.201
IN:                    fddf:f4ac:22f3::ffff:201
IN:
IN:  0 packages can be updated.
IN:  0 updates are security updates.
IN:
IN:  New release '18.04.4 LTS' available.
IN:  Run 'do-release-upgrade' to upgrade to it.
IN:
Statistics reset!
not yet applying: 256.0 250.0 2.0 1.0 256.0 250.0 2.0 1.0 a2b873dd-dbff-44e3-a45c-b7604ecf7a38
```

Fig. 3. A Live Demo of NECTOR

with Torrents (NECTOR) is to reduce satellite airtime costs. In our proposed demo, we would like to showcase NECTOR to the audience in an interactive HENCSAT test bench setup.

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