Multiple Drone Communications summary

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Version 3.0

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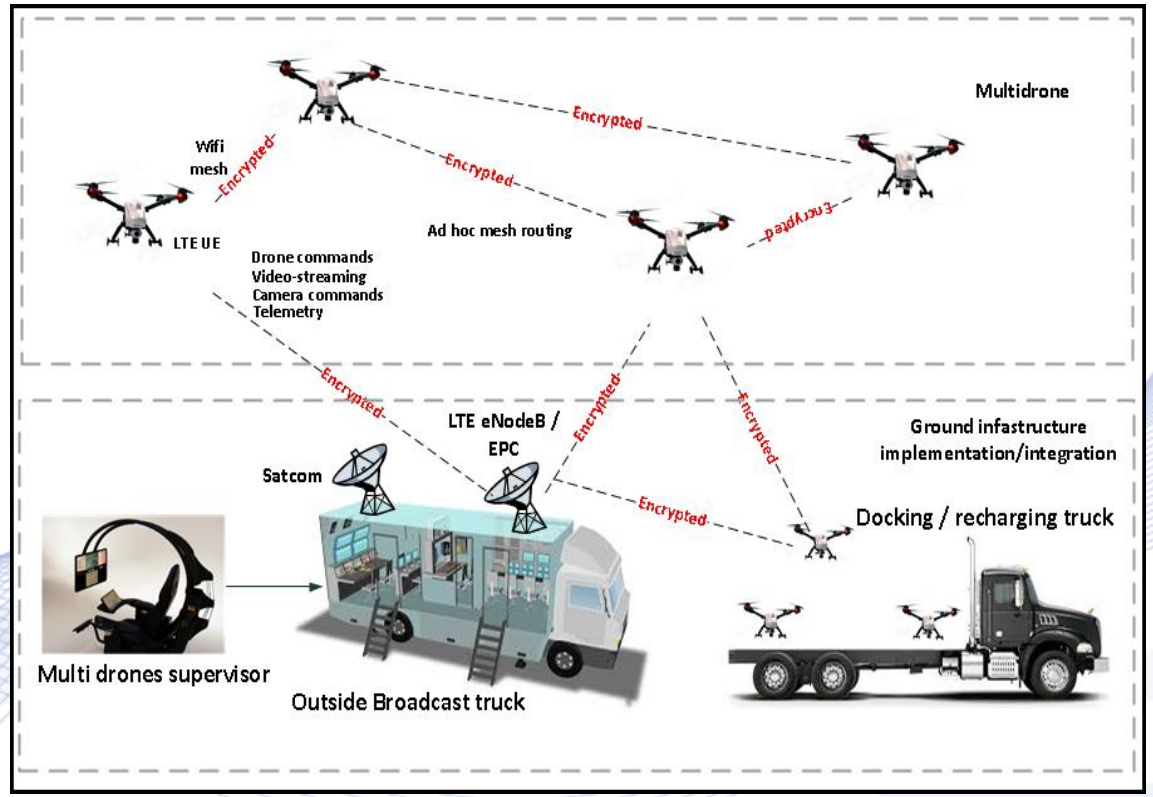
Drone Communications

- Communication infrastructure overview

- Communication issues
  - Video streaming

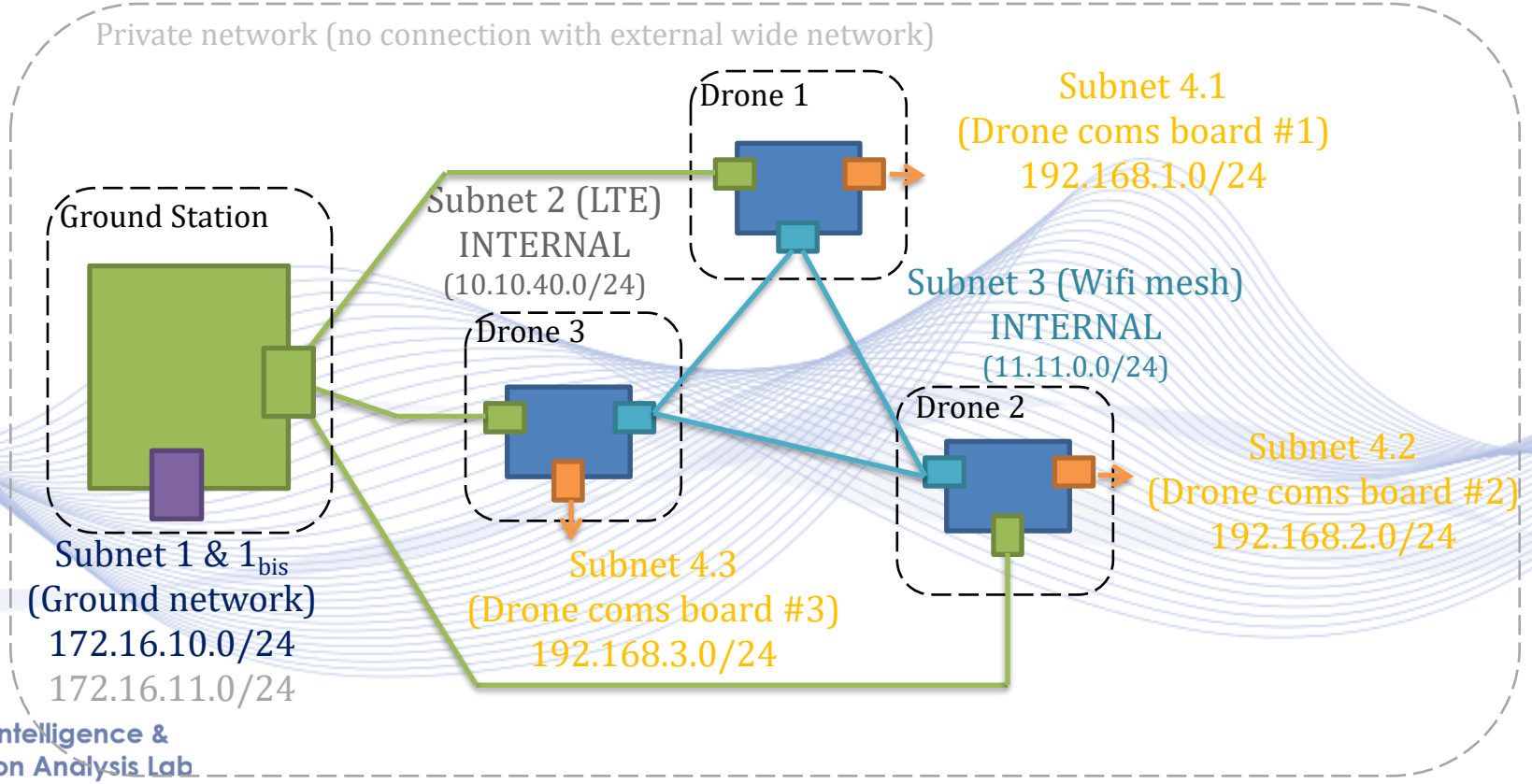
Drone Communications

- ***Drone2Ground communication***:
  - LTE solution (LTE user equipment on-board + LTE base station on ground).
  - Communication infrastructure should be fully independent of any public LTE operator.
- ***Drone2Drone Communication***:
  - WiFi mesh solution.



Drone Communications

Objective: to provide secured and resilient transparent IP access to drones and ground station (using both LTE and Wifi).



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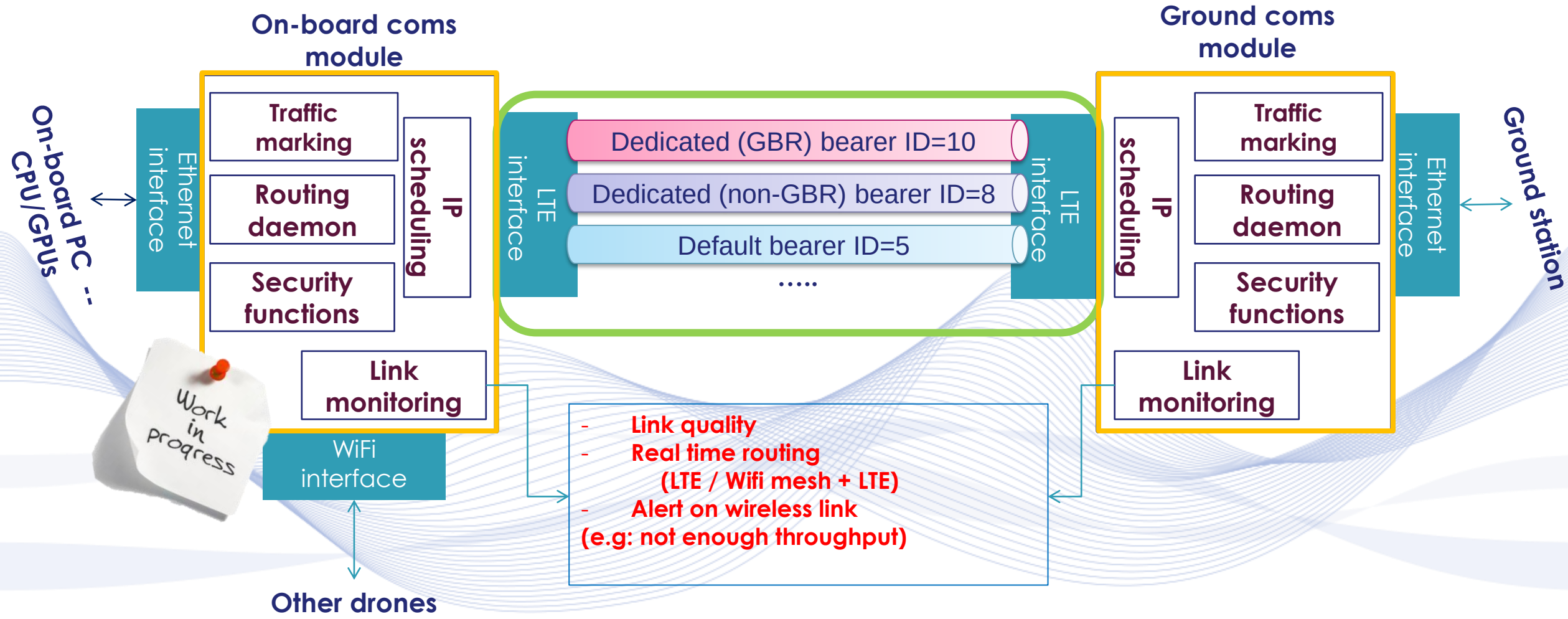
Drone Communications

- ***Default IP gateway*** to the ground station and to other drones.
- Route traffic to/from wireless link interfaces (LTE & Wi-Fi).
  - It is transparent to the users of the communication module. They do not need to know which link is used.

- ***Quality of Service*** (***QoS***) : mark and Schedule IP flows depending on applications

Drone Communications



Drone Communications

Radio requirements:

- High bandwidth > 30 Mbps (in average over the full network)
  - Support of several (e.g., $n = 3 - 5$) UAVs.
  - n Full HD cinematography video streams for shooting + n VGA navigation video streams + telemetry + a lot of control and metadata messages.
- Low latency for UAV control commands.
- High quality video is expected for TV broadcasting.
- Robust, resilient to failure and encrypted communication.

Drone Communications

- ***Ground Station*** (***GS***) communication module:
  - GS equipment is an IP router coupled with LTE+ WiFi modems.
  - It provides a transparent IP based interface between the software modules available on the network.

Drone Communications

Security analysis on communication.

Transmission threats:

- Jamming
- Passive threats
- Radio Sniffer Attack

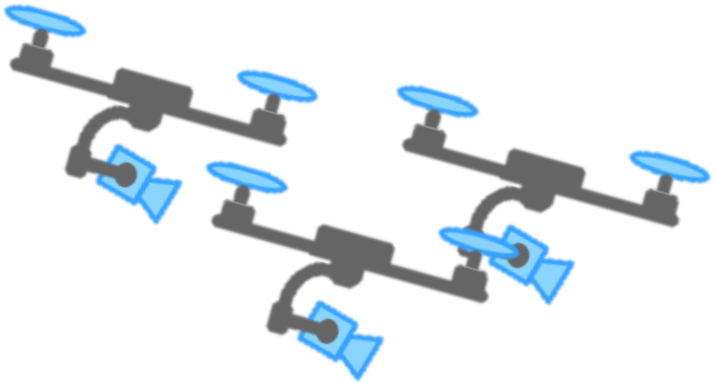
Drone Communications

Communication threats:

- Password-Based Attacks
- Data Modification
- Identity Spoo
- Sniffer Attack
- fingMan-in-the-Middle Attack
- Network Sniffer Attack.

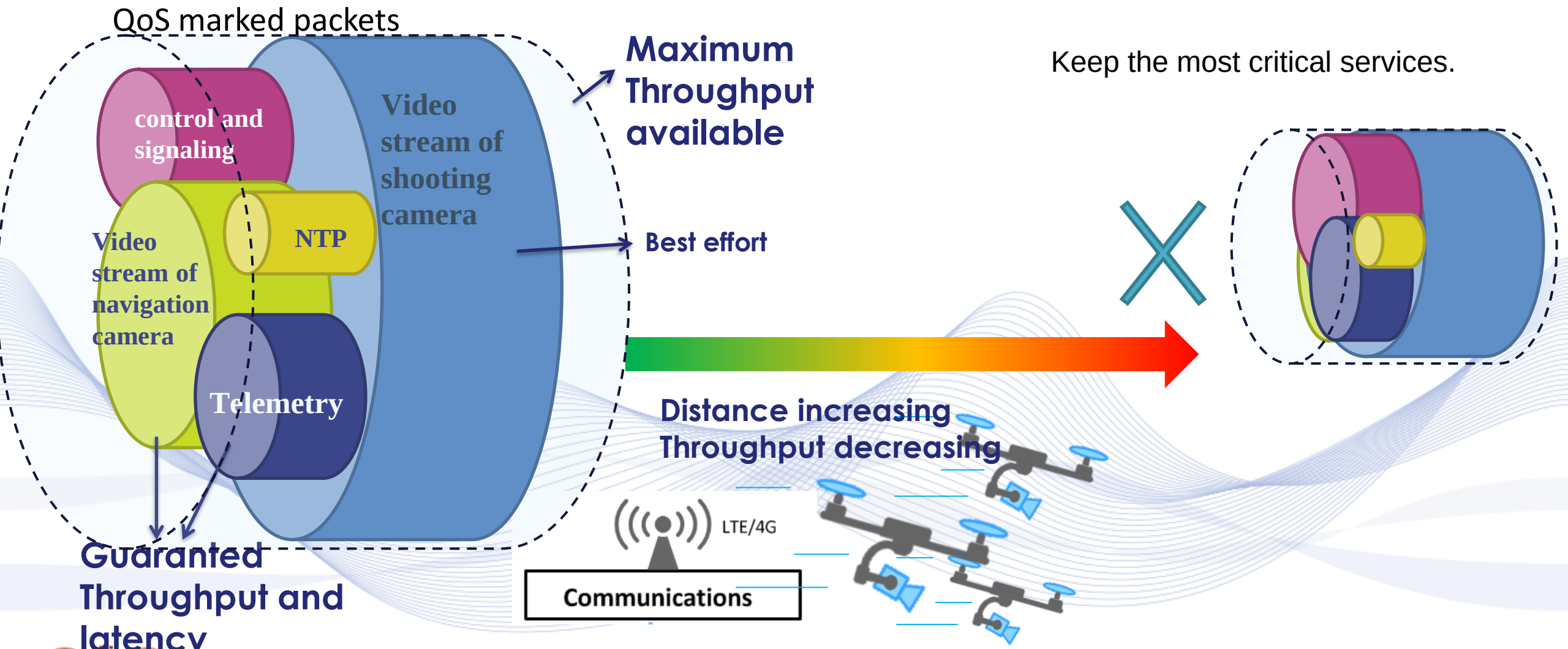
Drone Communications

- Quality of service radio profiles.
- Jamming detection and automatic best channel choice.



- LTE standard encryption.
- Multiple access with guaranteed bitrate.
- Physical authentication:SIM cards and IMSI numbers.
- White and black lists.
- Network monitoring (access, bitrate).

Drone Communications



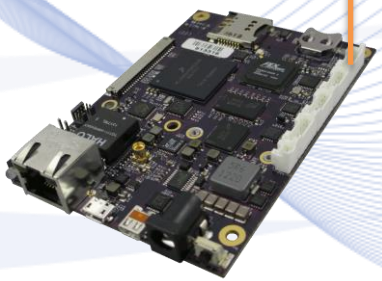
QoS concept explanation.

Drone Communications

Serial connection
(split cable)

USB connection

Serial and USB at
the same time
?



LTE/Wifi COM board

Pixhawk official
Telemetry module

Intel Nuc

Pixhawk telemetry.

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Multiple Drone Communications

- Communication infrastructure overview

- **Communication issues**
  - **Video streaming**

Drone Video Streaming

- Applications:
  - First Person View of drone's Field Of View.
  - **Real-time cinematographic video streaming of live events.**

Video Streaming specs

- Navigation camera video: one stream per drone.
- Cinematographic camera video: 1080p@25 fps per drone.
- Video compression: H.264.
- Communication load: 7 Mbps.
- Latency: as small as possible.
- Manual drone operation mode:
  - WiFi digital transmission or
  - RF analog video transmission.

Video Streaming specs

- Cinematographic camera:
  - E.g., Blackmagic Micro Cinema Camera with a motorised Panasonic x3 lens.

- Navigation camera, e.g.,:
  - Fatshark 700TVL (PAL output for analog communication).
  - Leopard CSI-2 MIPI camera (direct use of hardware acceleration).

Video Streaming specs

- Manual drone operation mode
  - WiFi digital video transmission.
  - RF analog video transmission.

Analog video transmission

RF communication addresses safety concerns:

- e.g., in case of LTE streaming failure.
- Backup solution: the navigation video stream will be sent to the pilot via RF in manual mode.

Thus, an analog video transmission is required.

- RF can also handle the commands to control the gimbal and the camera from a transmitter.
- The Pixhawk may receive at the same time commands coming from the RF receiver and from the onboard computer, which received it from the dashboard through the LTE.

Video Streaming specs

- Automatic drone operation mode:
  - WiFi digital video transmission.
  - **LTE digital video transmission.**
  - Multiple drones (2 video streams each).

Drone Digital Video Streaming Problem 1: Network

- Good quality video is massive in terms of rate requirements:
  - 1 second of 720p (1280×720 pixel) 8-bit video requires 65.92 Mbytes!
- Video compression must be used prior to streaming:
  - H264 & H265 coding are great candidates...
  - ... but they inevitably introduce delays (compression + decompression)
  - Lossy compression can offer a trade-off between latency & quality.
- Wireless communications may fail (distance, obstacles, other wireless networks etc).
- Which network protocol should be used?
  - Real-time Transport Protocol (RTP) with User Datagram Protocol (UDP)
  - TCP is also standardized for use with RTP, but favors reliability instead of timeliness.

Drone Digital Video Streaming Problem 1: Network

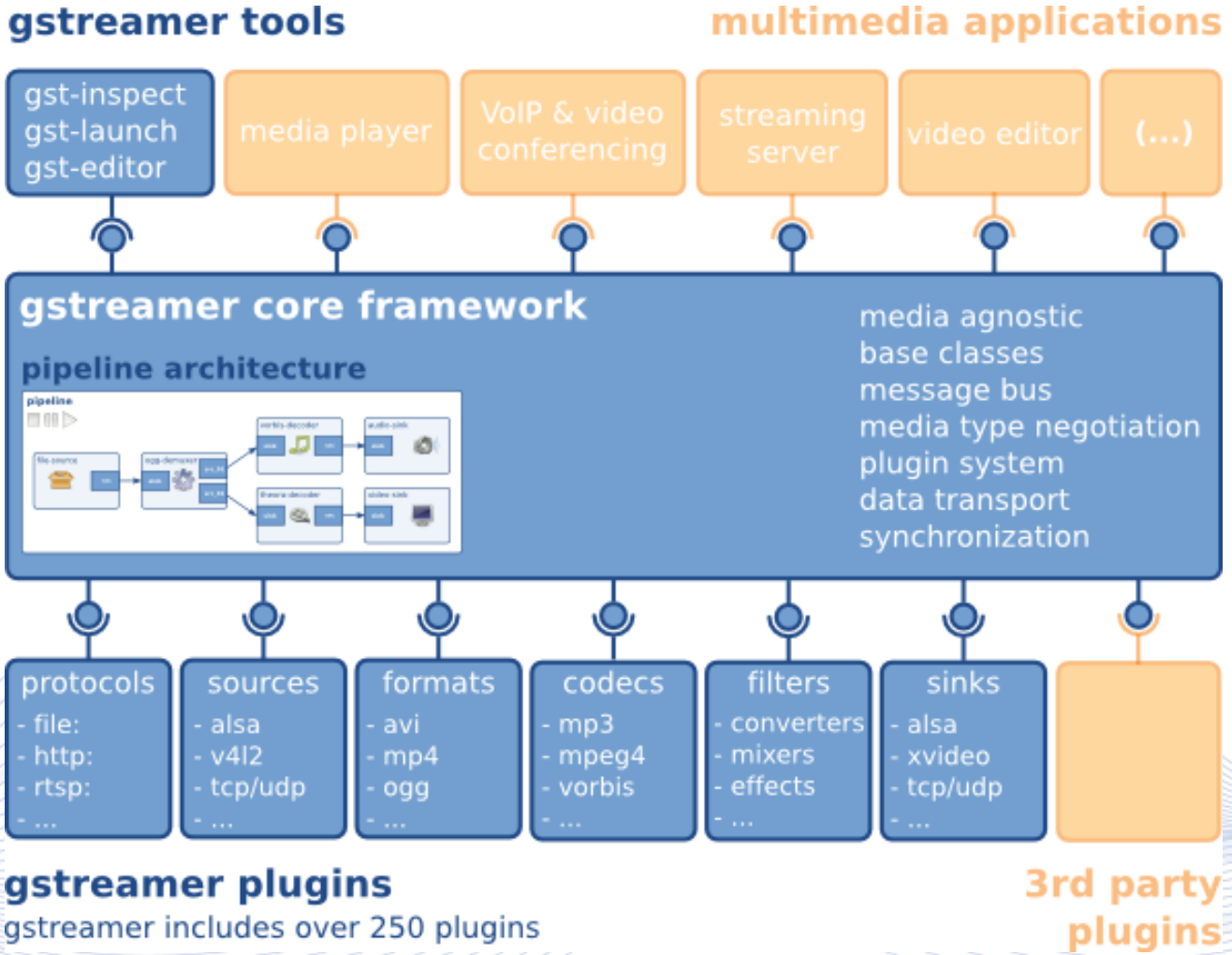
Video compression takes place on-board the drone embedded computer, e.g., NVIDIA Jetson TX2 module:

- Hardware accelerated image/video compression.
- A 256-core Pascal @ 1300MHz GPU with capability comparable to an Intel Xeon E5-2960 v4 CPU in Deep Learning tasks.

GStreamer

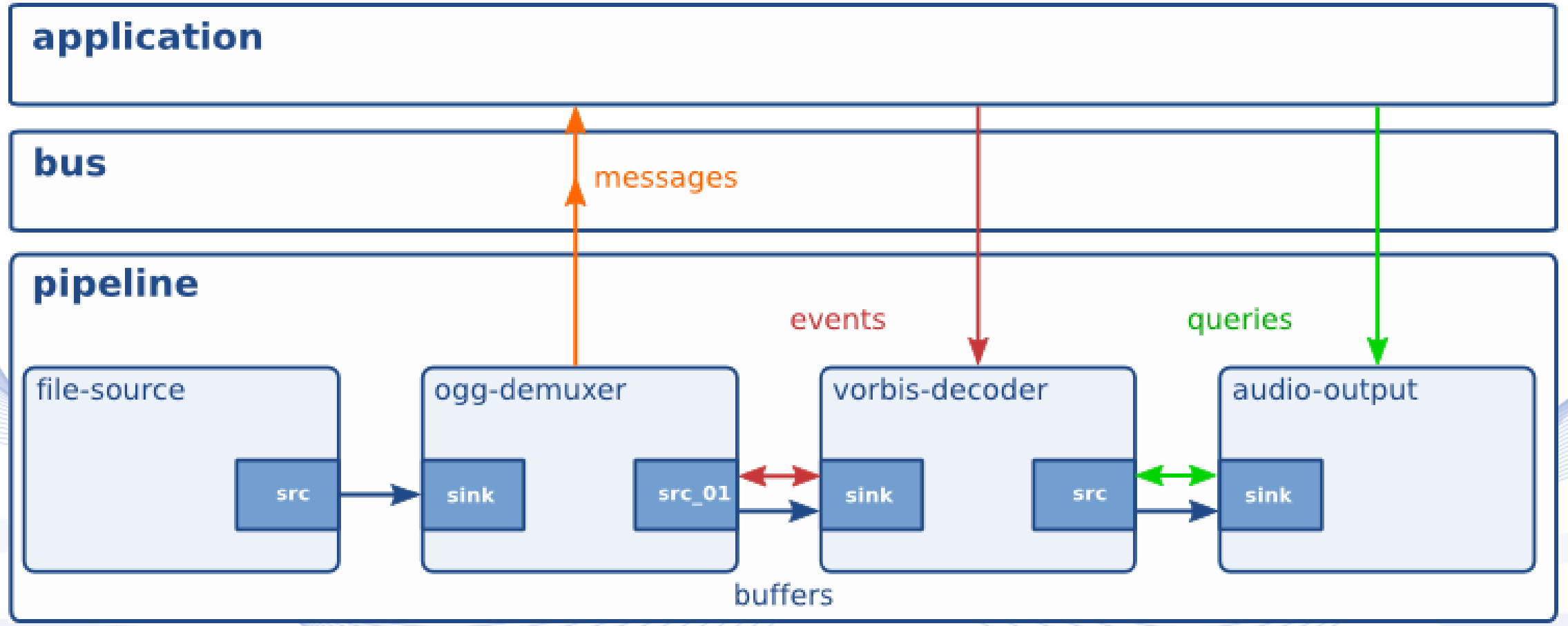
- A development framework for creating applications.
- Written in *C.*
- Pipeline Based.
- Uses and combines many different plugins.
- Mainly targeting ***Linux*** systems.
- Used as backend in many applications.

GStreamer



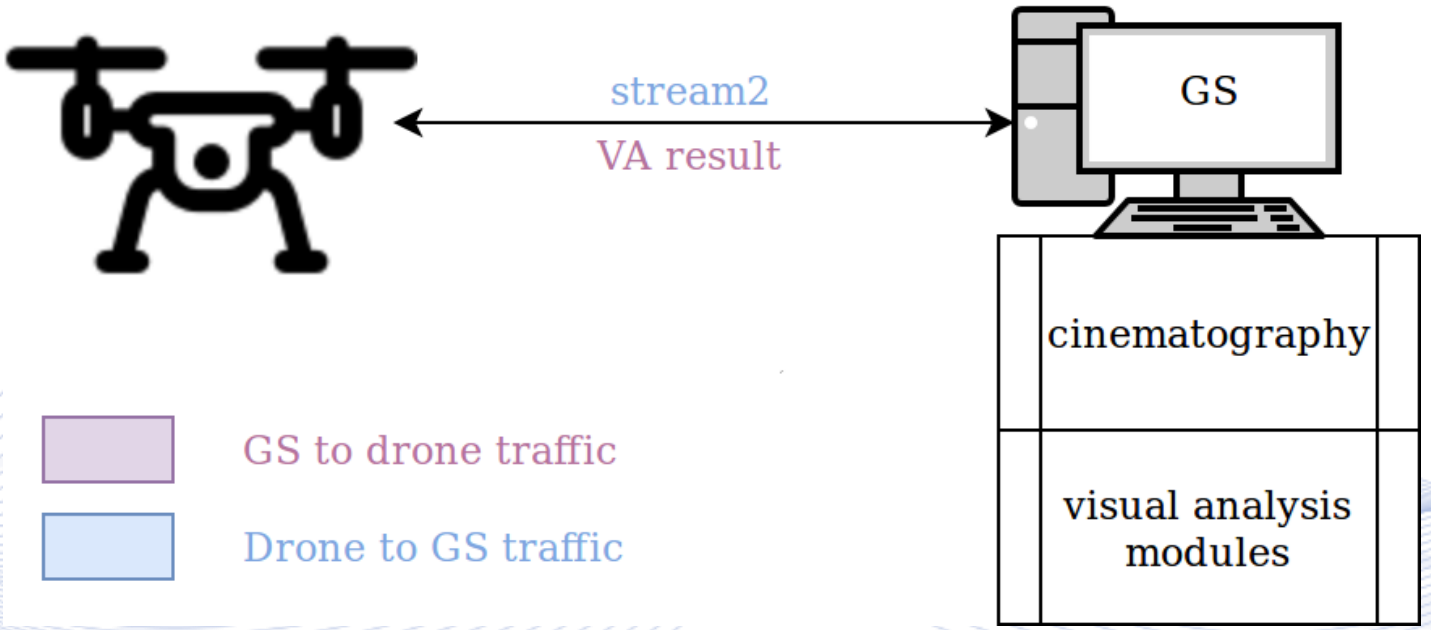
Gstreamer plugin architecture [GSP].

Gstreamer Communication



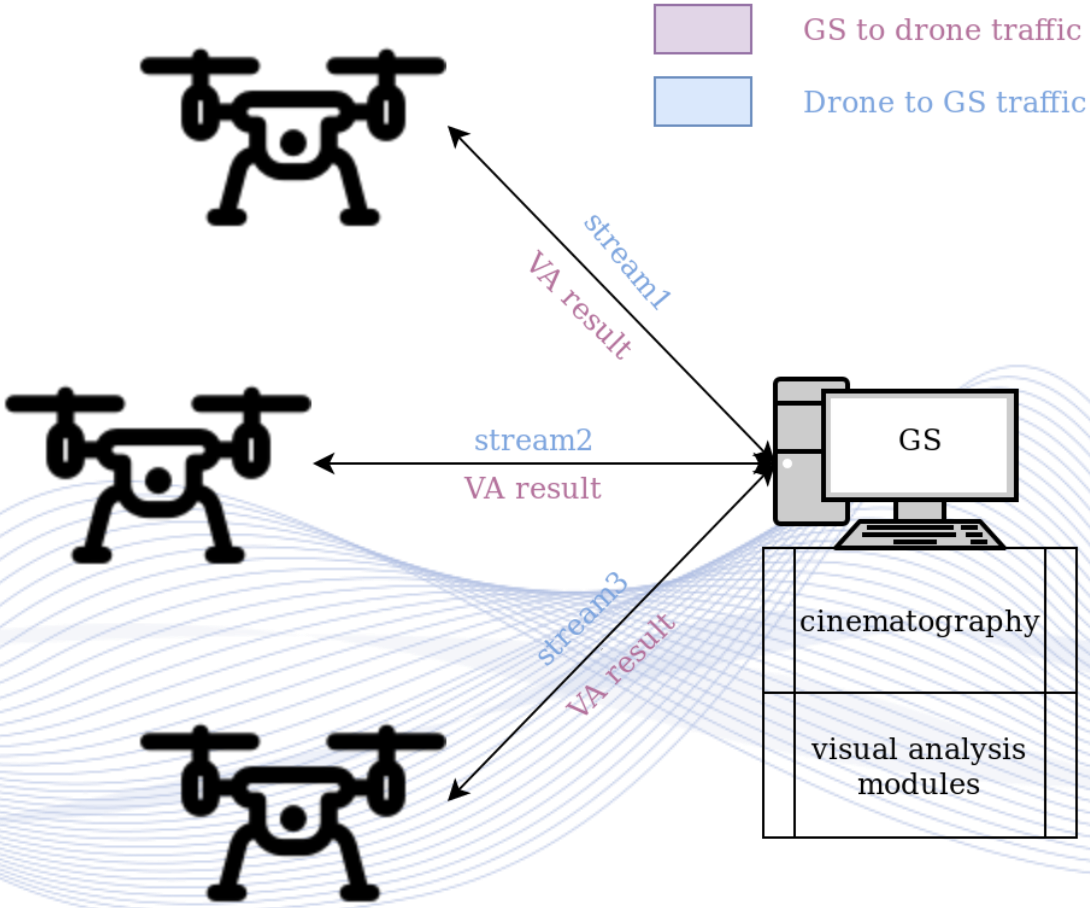
Application-Pipeline communication [APC].

Drone Digital Video Streaming Synchronization



One drone - one ground station communication.

Drone Digital Video Streaming Synchronization



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Mutiple drones - one ground station communications.

Drone Digital Video Streaming Synchronization

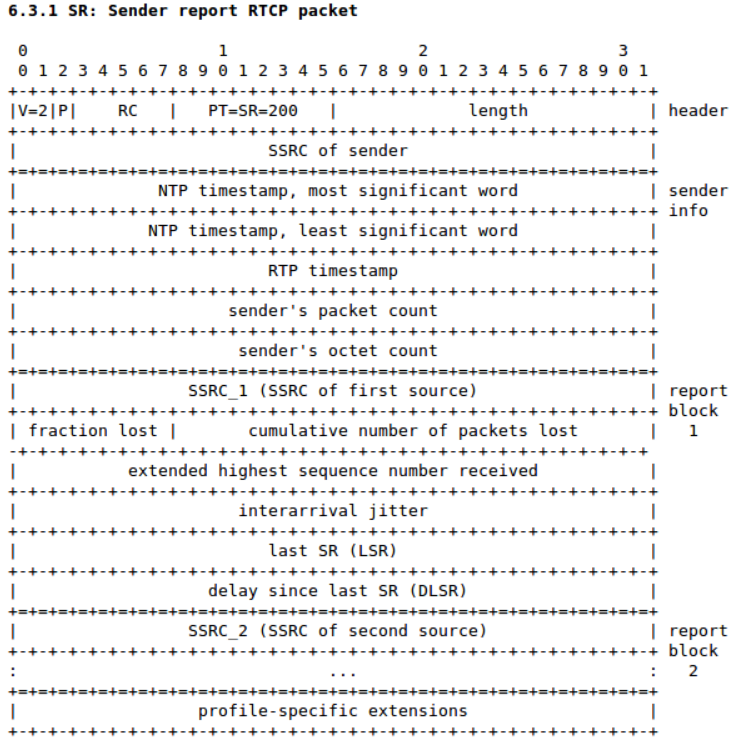
NTP timestamp (64 bits):

- It indicates the wallclock time when this report was sent so that it may be used in combination with timestamps returned in reception reports from other receivers to measure round-trip propagation to those receivers.

How to synchronize all streams?

- RTP Control Protocol (RTCP) may be used in conjunction with RTP.

6.3.1 SR: Sender report RTCP packet



Video and metadata Synchronisation

Synchronization must be based on existing standards:

- NTP (Network Time Protocol – RFC 1305)
  - Provide common clock – absolute 64 bits timestamp - for all HW: UAVs & BS
  - Clock of the base station is collected via GPS.
  - Use of client request (rather than server broadcast).

Video and metadata Synchronisation

- RTP (Real-Time Transport Protocol – RFC 3550) over UDP for video streaming.
  - Each image is timestamped (with a 32-bit RTP timestamp)
- RTCP (Real-Time Control Protocol – RFC3550) is also used for on-ground synchronization of video streams coming from different UAVs:
  - SR packet (Sender report) holds the correspondence between the RTP timestamp and the absolute 64-bit timestamp (system hour).

References

[GSP] https://gstreamer.freedesktop.org/documentation/application-development/introduction/images/gstreamer-overview.png

[APC] https://gstreamer.freedesktop.org/documentation/application-development/introduction/images/communication.png

Q & A

Thank you very much for your attention!

More material/lectures in
http://icarus.csd.auth.gr/cvml-web-lecture-series/

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