Eminent Feed System 5G47

Comprehensive System Documentation

Project Team

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1 Goal of the Project

The primary goal of the **Eminent Feed System 5G47** is to design, specify, and implement a high–performance wireless communication system operating exclusively in the frequency band 5.47–5.725 GHz, compliant with European regulatory frameworks.

This project aims to deliver a fully documented, production–ready solution that can be integrated into embedded computing platforms through the software library `eminentFeedSystem5G47`. The library exposes a simple and extensible API for establishing sessions, exchanging data packets, and managing transmission priorities.

The intended outcomes of this project include:

- A communication system that ensures low–latency and high–throughput data transfer within the 5.47–5.725 GHz band.
- Modular architecture that separates application–level interfaces from the physical transmission layer, enabling scalability and easier maintenance.
- Clear technical documentation describing each subsystem, its role, inputs, outputs, and dependencies.
- Hardware and software designs that prioritize commercially viable, standards–compliant components.
- A certification–ready design pathway that aligns with the Radio Equipment Directive (RED) and relevant ETSI standards.

In summary, the **Eminent Feed System 5G47** is not a proof–of–concept but a blueprint for a commercial–grade product, with emphasis on regulatory compliance, modularity, and high technical performance.

2 Project Boundaries

The **Eminent Feed System 5G47** defines clear boundaries that separate its responsibilities from external systems and environments. The system is designed as a complete two–way communication solution, including both the airborne unit and the ground unit, ensuring continuous bidirectional data exchange. The purpose of this section is to establish what belongs inside the scope of the project and what remains outside.

In–Scope Elements

The following elements are explicitly covered by the project:

- **Software library `eminentFeedSystem5G47`** providing APIs for session management, bidirectional data transmission, and priority–based scheduling on both ends of the link.
- **End–to–end communication chain** covering all layers from application API calls down to the physical radio interface, for both the airborne and ground units.
- **Defined modular architecture**, including packetization, reliability mechanisms, transport abstraction, medium access control, baseband processing, RF conversion, and antenna subsystems.
- **Bidirectional control and data flow**:
  - Uplink (air to ground): video streams and telemetry parameters.
  - Downlink (ground to air): command and configuration data.
- **Control and management features** such as frequency selection (DFS compliance), power control (TPC), and telemetry reporting.
- **Documentation and certification pathway** covering regulatory compliance, modular specifications, and hardware/software design choices.

Out–of–Scope Elements

The following elements are outside the responsibility of this project:

- **External computing platforms**: the system assumes integration with third–party onboard computers or ground stations, but their design is out of scope.
- **Application logic**: higher–level applications using the communication library are not part of the project.
- **Alternative frequency bands**: only 5.47–5.725 GHz is considered in this version of the system.
- **External networking infrastructure**: cellular networks, satellites, or other connectivity technologies are excluded.
- **Non–communication functions**: power supply units, flight control logic, or mechanical design are not covered.

Boundary Statement

In short, the system begins at the application API call into `eminentFeedSystem5G47` and ends at the antenna interface, for both the airborne unit and the ground unit. It includes all software and hardware modules required to make bidirectional transmission functional and compliant. Anything beyond the antenna or above the application API is considered external to the project.

3 Selected Frequency Band and Target Parameters

The **Eminent Feed System 5G47** operates exclusively in the frequency range of **5.47–5.725 GHz**, identified in Europe as WAS/RLAN. This band provides a balance between regulatory acceptance, available bandwidth, and propagation characteristics, making it suitable for low–latency, high–throughput, and long–range communication.

Target Parameters

The project defines the following technical objectives:

- **Uplink (Air Unit to Ground Unit):**
  - Primary video stream: target **15 Mb/s** (H.265, 1080p60).
  - Adaptive bitrate range: **4–40 Mb/s**, depending on channel conditions and selected bandwidth.
  - End–to–end latency target: **60–120 ms**, including radio transmission, encoding, and buffering.
  - Telemetry data: continuous **5–20 kb/s**, with peaks up to **100 kb/s**.
- **Downlink (Ground Unit to Air Unit):**
  - Command and control: typical **20–100 kb/s**, with strict latency target of **$\leq$50 ms**.
  - Configuration and service data: up to **1 Mb/s** for control, and up to **5 Mb/s** for non–real–time transfers.

Radio Parameters

The communication system shall operate with the following radio characteristics:

- Channel bandwidth: **40 MHz** default, with **80 MHz** enabled under favorable conditions; fallback to 20 MHz for degraded links.

- Modulation and coding: adaptive, up to **64–QAM, r≈3/4**.
- MIMO configuration: **2×2** spatial streams for increased throughput and robustness.
- Error correction: hybrid ARQ and forward error correction (RaptorQ/Reed–Solomon) with 20–40% overhead on video streams.
- Regulatory compliance: maximum **1 W e.i.r.p.**, including transmit power and antenna gain, with mandatory DFS and TPC features.

Design Implications

These parameters imply that the system will:

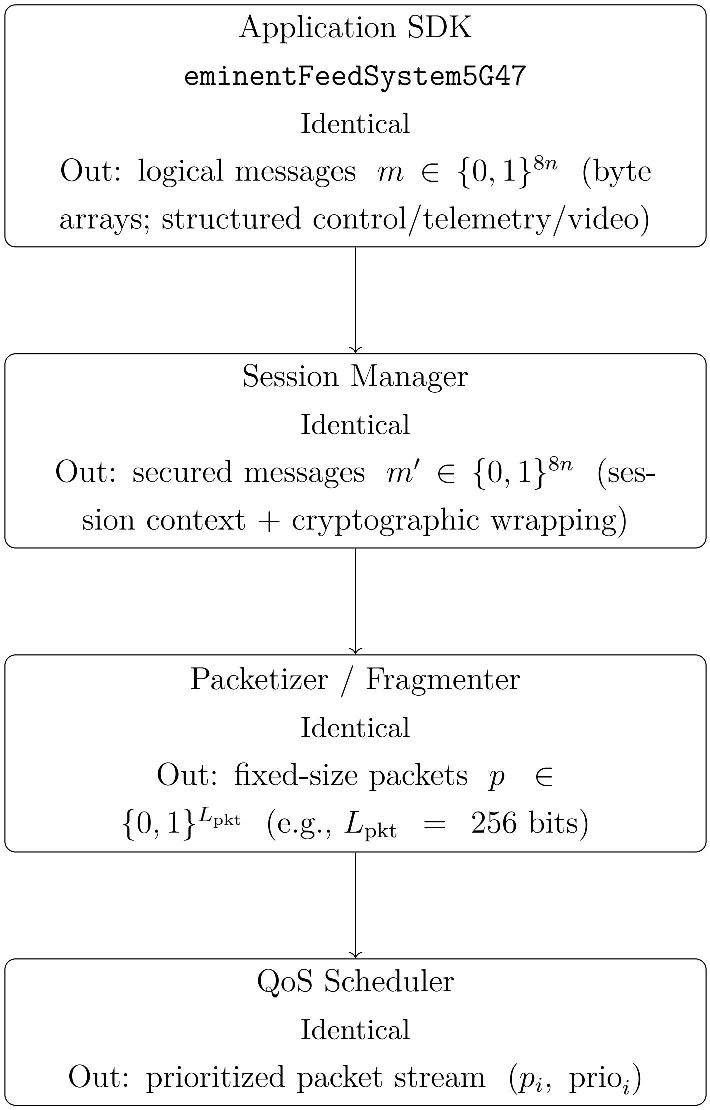
- Provide stable **20 km line–of–sight communication** using a compact antenna on the airborne unit (2–6 dBi) and a high–gain directional antenna on the ground unit (12–24 dBi).
- Ensure resilient video streaming by dynamically adapting bitrate and FEC overhead in response to SNR and packet loss.
- Guarantee that command and control data always preempt lower–priority traffic, maintaining safe latency requirements under all conditions.

In summary, the chosen frequency band and parameters define a system capable of delivering real–time high–definition video and reliable control over long distances, while fully adhering to European regulatory requirements.

4 Modular Plan

The **Eminent Feed System 5G47** is designed as a modular architecture. Each module has a well–defined role, clearly specified input domains, and an explicit designation whether it is identical on both the air unit and the ground unit, or role–specific. This modularity guarantees maintainability, scalability, and certifiability of the final product. *Convention for diagrams: each node shows only* ***Out:*** *(output domain). The input of a module equals the output of the preceding module.*

Overview Diagram (Part 1 of 3: Application SDK to QoS Scheduler)



Overview Diagram (Part 2 of 3: Reliability to PHY)

Reliability Engine (ARQ/FEC)
Identical
Out: error-protected stream $c_j \in \{0,1\}^M$ (coded blocks / parity added)

$\downarrow$

Framing (RTP-like)
Identical
Out: transmission frames $f_k \in \{0,1\}^N$ (bit sequences with headers/timestamps)

$\downarrow$

Transport Abstraction Layer
Identical
Out: MAC frames $u_\ell \in \{0,1\}^N$ (link-ready bit sequences)

$\downarrow$

MAC / Baseband
Identical
Out: complex baseband symbols $s[n] \in \mathbb{C}$ (IQ stream)

$\downarrow$

PHY / Modem
Identical
Out: analog waveform (IF) $x_{\mathrm{IF}}(t) \in \mathbb{R}$

Overview Diagram (Part 3 of 3: RF to Antenna)

RF Front-End
Role-specific
Out: RF signal $x_{\mathrm{RF}}(t)$ at 5.47–5.725 GHz

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Antenna Subsystem
Role-specific
Out: radiated electromagnetic field $\vec{E}, \vec{H}$ (free-space propagation)

Module Descriptions

- **Application SDK [Identical]**: Provides the API for applications to send and receive structured data. Converts API calls into logical byte-array messages.
- **Session Manager [Identical]**: Establishes secure sessions, attaches session context and cryptographic data.
- **Packetizer / Fragmenter [Identical]**: Converts byte arrays into fixed-size packets (e.g. 256-bit sequences).
- **QoS Scheduler [Identical]**: Orders packets by priority, ensures timing guarantees.
- **Reliability Engine [Identical]**: Adds redundancy via ARQ/FEC; produces error-protected streams.
- **Framing (RTP-like) [Identical]**: Creates bit-sequence frames with timestamps and markers.
- **Transport Abstraction Layer [Identical]**: Provides unified interface to MAC/PHY.
- **MAC / Baseband [Identical]**: Medium access control, symbol mapping, MIMO stream management.
- **PHY / Modem [Identical]**: Performs modulation and coding; outputs analog waveforms at IF.
- **RF Front-End [Role-specific]**: Air unit uses lightweight PA/LNA and compact antennas; ground unit uses high-power PA/LNA and large directional antennas.
- **Antenna Subsystem [Role-specific]**: Air unit uses small omni/patch; ground unit uses high-gain directional antennas with optional tracking.

5 Detailed Module Specifications

This section provides a technical description of each module in the **Eminent Feed System 5G47**. For every subsystem, we specify its role, data domain, implementation technology, target platform, estimated effort, and any differences between the airborne and ground units.

Application SDK [Identical]

Role: Provides an API for applications to send and receive structured data (telemetry, control commands, video frames).
Data domain: Out: logical messages $m \in \{0,1\}^{8n}$ (byte arrays).
Implementation technology: C++17 library (with Python bindings).
Target platform: Embedded Linux (ARM SoC, e.g. NXP i.MX8, Nvidia Jetson).
Estimated effort: 80 hours.
Air vs. Ground: Identical implementation.

Session Manager [Identical]

Role: Establishes secure sessions, negotiates parameters, and attaches session context.
Data domain: Out: secured messages $m' \in \{0,1\}^{8n}$.
Implementation technology: C++17 with OpenSSL or mbedTLS.
Target platform: Embedded Linux (same as SDK).
Estimated effort: 100 hours.
Air vs. Ground: Identical implementation.

Packetizer / Fragmenter [Identical]

Role: Splits byte arrays into fixed-size packets with headers.
Data domain: Out: packets $p \in \{0,1\}^{L_{\text{pkt}}}$ (e.g., $L_{\text{pkt}} = 256$ bits).
Implementation technology: C++17, custom packet format with CRC.
Target platform: Embedded Linux.
Estimated effort: 60 hours.
Air vs. Ground: Identical implementation.

QoS Scheduler [Identical]

Role: Prioritizes traffic by class (control $\rightarrow$ highest, telemetry $\rightarrow$ medium, video $\rightarrow$ elastic).

Data domain: Out: prioritized packet stream $(p_i,\ \text{prio}_i)$.
Implementation technology: C++17 with real-time scheduling algorithms.
Target platform: Embedded Linux.
Estimated effort: 120 hours.
Air vs. Ground: Identical implementation.

Reliability Engine (ARQ/FEC) [Identical]

Role: Ensures data reliability with hybrid ARQ and forward error correction.
Data domain: Out: coded blocks $c_j \in \{0,1\}^M$.
Implementation technology: C++17, libraries for RaptorQ or Reed–Solomon.
Target platform: Embedded Linux.
Estimated effort: 150 hours.
Air vs. Ground: Identical implementation.

Framing (RTP-like) [Identical]

Role: Creates lightweight frames with timestamps and sequence numbers.
Data domain: Out: transmission frames $f_k \in \{0,1\}^N$.
Implementation technology: C++17, custom lightweight framing protocol.
Target platform: Embedded Linux.
Estimated effort: 80 hours.
Air vs. Ground: Identical implementation.

Transport Abstraction Layer [Identical]

Role: Provides a unified API for lower layers, hiding physical details.
Data domain: Out: MAC frames $u_\ell \in \{0,1\}^N$.
Implementation technology: C++17, HAL (hardware abstraction layer).
Target platform: Embedded Linux.
Estimated effort: 100 hours.
Air vs. Ground: Identical implementation.

MAC / Baseband [Identical]

Role: Medium access, channel coordination, and MIMO stream management.
Data domain: Out: IQ symbols $s[n] \in \mathbb{C}$.
Implementation technology: DSP firmware in C, accelerated with SIMD.

Target platform: High-performance SoC with integrated DSP (e.g. Qualcomm Atheros, TI Keystone).
Estimated effort: 400 hours.
Air vs. Ground: Identical implementation.

PHY / Modem [Identical]

Role: Modulates and codes digital symbols into analog waveforms.
Data domain: Out: IF waveform $x_{\mathrm{IF}}(t) \in \mathbb{R}$.
Implementation technology: DSP firmware in C/assembly, hardware-accelerated modem blocks.
Target platform: Same SoC/DSP as MAC.
Estimated effort: 500 hours.
Air vs. Ground: Identical implementation.

RF Front-End [Role-specific]

Role: Converts intermediate frequency to 5.47–5.725 GHz RF and amplifies.
Data domain: Out: RF signal $x_{\mathrm{RF}}(t)$.
Implementation technology: Analog RF hardware (PA, LNA, mixers, filters).
Target platform: Custom RF PCB design, using components from Analog Devices, Qorvo, etc.
Estimated effort: 600 hours (design, layout, prototyping).
Air vs. Ground: Different power and sensitivity requirements.

Antenna Subsystem [Role-specific]

Role: Converts electrical RF signals into electromagnetic waves.
Data domain: Out: radiated EM fields $(\vec{E}, \vec{H})$.
Implementation technology: Commercial off-the-shelf antennas (patch/omni for air, directional for ground).
Target platform: Integrated with RF front-end, external antenna mount.
Estimated effort: 80 hours (integration and testing).
Air vs. Ground: Different antenna size and gain.

6 Module Implementation Summary

The following table summarizes the implementation technology, target platform, and estimated effort for each module of the **Eminent Feed System 5G47**.

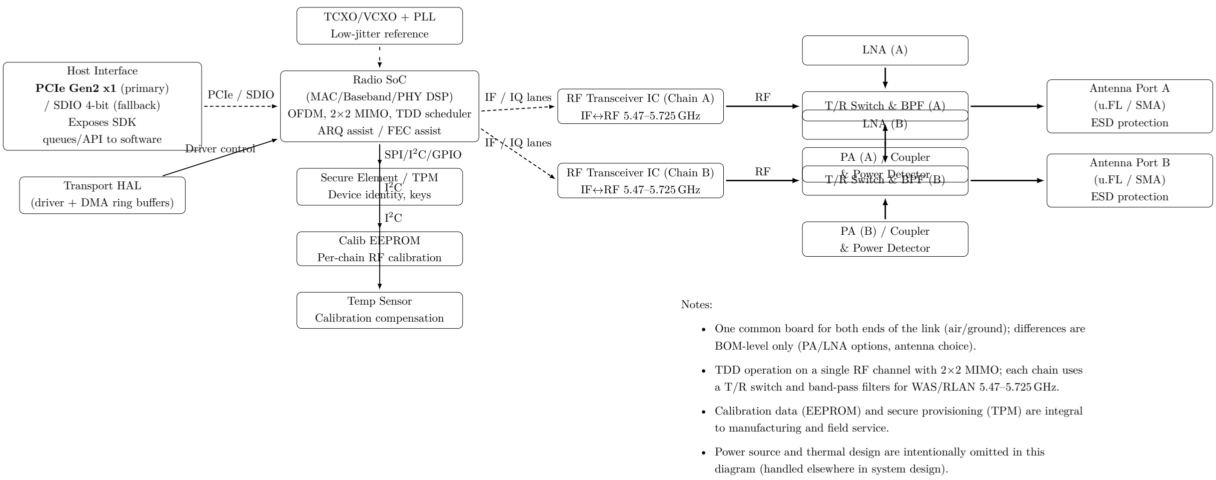
Module	Implementation Technology	Target Platform	Effort [h]
Application SDK	C++17 library (with Python bindings)	Embedded Linux (ARM SoC: NXP i.MX8, Nvidia Jetson)	80
Session Manager	C++17 + OpenSSL/mbedTLS	Embedded Linux	100
Packetizer / Fragmenter	C++17, custom packet format with CRC	Embedded Linux	60
QoS Scheduler	C++17 with real-time scheduling	Embedded Linux	120
Reliability Engine (ARQ/FEC)	C++17 + RaptorQ/Reed–Solomon libraries	Embedded Linux	150
Framing (RTP-like)	C++17, custom lightweight framing	Embedded Linux	80
Transport Abstraction Layer	C++17 HAL	Embedded Linux	100
MAC / Baseband	DSP firmware in C with SIMD acceleration	High-performance SoC/DSP (Qualcomm Atheros, TI Keystone)	400
PHY / Modem	DSP firmware in C/assembly, hardware-accelerated	Same SoC/DSP as MAC	500
RF Front-End	Analog RF hardware (PA, LNA, mixers, filters)	Custom RF PCB (Analog Devices, Qorvo)	600
Antenna Subsystem	COTS antennas (patch/omni, directional)	Integrated with RF front-end	80
Total Effort	—		**2270**

7 EFS5G47 Transceiver Board (2×2 MIMO, TDD)

This section defines the common **Transceiver Board** used on both ends of the link (air and ground). The board exposes a high-speed host interface for the software stack (`eminentFeedSystem5G47`) and implements a dual-chain 5.47–5.725 GHz RF path with time-division duplexing (TDD). *Power source and thermal management are out of scope of this section.*

Signal Domain Legend

Common Board Diagram (used for both air and ground)



8 Bill of Materials (BoM)

This section enumerates the required components for one complete link (airborne + ground unit). Both ends share the same transceiver board design; differences are limited to PA/LNA choice and antenna type.

Core Components

Component	Model	Detail [EUR]	Bulk [EUR]	Lead Time
RF Transceiver IC	AD9361BBCZ (Analog Devices)	207	166 (@1k)	8–12 wks
Radio SoC (MAC/PHY DSP)	Qualcomm Atheros QCA9984	18	12 (@1k)	6–8 wks
Secure Element	Microchip ATECC608A	0.74	0.46 (@1k)	2–3 wks
TCXO 40 MHz	Abracon ASTX-H11	2.67	1.38 (@1k)	3–5 wks
Calib EEPROM	24C02 (Microchip)	0.28	0.14 (@10k)	2–3 wks

RF Front-End & Antennas

Component	Model	Detail [EUR]	Bulk [EUR]	Lead Time
PA/LNA (air)	Qorvo SPF5043Z	7.36	4.60 (@1k)	6–8 wks
PA (ground)	Qorvo QPA0506	132	92 (@100)	10–12 wks
BPF 5 GHz	Murata SAFEA1G57FA0F00	1.10	0.55 (@10k)	4 wks
Antenna Air (patch)	Taoglas FXP611	4.60	2.94 (@500)	2–4 wks
Antenna Ground (19 dBi)	L-Com HG5819P	60	46 (@100)	2–4 wks
Connectors/ESD kit	Amphenol RF SMA/u.FL	1.38	0.74 (@1k)	2–3 wks

Summary

For one complete link (1 drone + 1 ground unit, including two transceiver boards):

- **Total detail cost:** € 1,270
- **Total bulk cost (@500+):** € 930
- **Lead time:** limited by AD9361 (≈ 12 weeks)

9 Regulatory Authorization and Certification Requirements

To lawfully market and operate the **Eminent Feed System 5G47** in Poland without requiring each end-user to file complex permits, the following national and European authorizations or certifications are necessary:

Required Documents and Authorizations

- **Type Approval / Radio Equipment Certification (RED Compliance) Description:** Official certification that a specific radio device model meets all essential requirements of the EU Radio Equipment Directive (2014/53/EU) including RF performance, EMC, health & safety, usage of spectrum. **Issuing Authority:** A notified body authorized to test and certify radio equipment under RED in Europe (for Poland usually an accredited laboratory + Polish national regulator oversight). **Approximate Costs:** Varies widely: laboratory testing, documentation, compliance audits — can range from tens of thousands to >100 000 EUR for complex devices. **Legal Assistance / Application Costs:** Legal, technical consulting and compliance documentation support may add additional tens of thousands of EUR for a commercial product. **Procedure & Timeline:** Prepare technical documentation (test reports, risk analysis, EMC, RF, safety, etc.), submit to notified body, perform conformity assessment, get certification — typically **3 to 9 months**.

- **National Registration / Notification to UKE (Poland) Description:** After obtaining RED/Type Approval, the device must be registered / notified in the Polish national regulator's database of radio equipment and possibly obtain a permit or registration certificate for use of the frequency bands (WAS/RLAN). **Issuing Authority:** Urząd Komunikacji Elektronicznej (UKE). **Approximate Costs:** Application / registration fees set by UKE (relatively modest compared to certification) — typically in the low thousands PLN or less. **Legal / Application Costs:** Preparation of the dossier, interaction with UKE, possibly legal support — additional cost of several thousand EUR. **Procedure & Timeline:** Submit request / dossier to UKE after type approval, UKE validates compliance, issues registration. Timeline: **several weeks to a few months** depending on backlog.

Notes and Considerations

- The **RED (EU) certification** is the main barrier; once a device is certified and registered, individual users do *not* need separate permits.
- National spectrum allocation / notification ensures the device is authorized to use the 5.47–5.725 GHz band under Polish law (WAS/RLAN).
- In Poland, there is also the concept of a *Świadectwo operatora urządzeń radiowych* (operator's radio license) for individuals operating transmitters — but for consumer devices normally this is not required for each user if the device is already certified/registered. :contentReference[oaicite:0]index=0
- Risks include regulatory changes, delays in notified bodies, requirement to re-certify after hardware revisions, or national restrictions on DFS usage.

Overall Cost and Timeline Estimate

Assuming all certification and registration processes are run in parallel:

- **Total certification and legal cost (detail level):**
  - RED / Type Approval: ~50,000–100,000 EUR
  - Legal, compliance documentation, UKE filings: ~10,000–20,000 EUR
  - **Combined total: ~60,000–120,000 EUR**
- **Total timeline:** ~6–9 months for complete approval (parallel processes).
- **Outcome:** Once completed, devices can be freely marketed and used in Poland and the EU without end-user permits.