PROJECT DELIVERABLE REPORT

Introducing advanced ICT
and Mass Evacuation Vessel design
to ship evacuation and rescue systems

D5.16 PaMEAS hardware and software components integration (V2)

A holistic passenger ship evacuation and rescue ecosystem

MG-2-2-2018

Marine Accident Response

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0.1	01/04/2022	UAegean	Report write-up
0.2	01/05/2022	UAegean	1st version of Deliverable
0.3	20/09/2022	UAegean	2nd version of Deliverable
0.4	20/12/2022	UAegean	Further additions
0.9	12/01/2023	UAegean	Internal Review (version send to reviewers)
1.0	30/03/2023	UAegean	Version ready for submission

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Abbreviations

2FA	Two-Factor Authentication
3GPP	3rd Generation Partnership Project
4G	Fourth generation mobile communication network
5G	Fifth generation mobile communication network
5GC	5G core
ALE	Analytics Location Engine
AoA	Angle-of-Arrival
AoD	Angle-of- Departure
AP	Access Point
API	Application Program Interface
BRMS	Business Rules Management System
BLE	Bluetooth Low Energy
CN	Core Network
CRM	Customer Relationship Management
DFB	Data Fusion Bus
DIDs	Disposable Ids
DSS	Decision Support Systems
DVI	Digital Visual Interface
ECs	Evacuation Coordinators
EP	Evacuation Plan
EPC	Evolved Packet
EPG	Evolved Packet Gateway
GA	Grant Agreement
HTTP	Hypertext Transfer Protocol
IAP	Instant Access Point
IMEI	International Mobile Equipment Identity
IMSI	International mobile subscriber identity
IoT	Internet of Things
IT	Information Technology
JVM	Java Virtual Machine
LAN	Local Area Network
LTE	Long Term Evolution
MAC	Media Access Control
MEE	Marine Emergency Evacuation
MEV	Massive Evacuation Vessel
MME	Mobility Management Entity
MSISDN	Mobile Station International Subscriber Directory Number
MSRP	Message Session Relay Protocol
NMS	Network Management System
NFV	Network Functions Virtualization
NFVI	Network Functions Virtualization Infrastructure
NR	New Radio
OIDC	OpenID Connect
PaMEAS	Passengers Mustering and Evacuation Process Automation System
PII	Personally Identifiable Information
PIMM	PALAEMON Incident Management Module
RAN	Radio Access Network
PMS	People Management System
RF	Radio Frequency
RO	Resource Orchestrator
RSSI	Received Signal Strength Indicator
RTLS	Real -Time Locating Systems
RTP	Real-time Transport Protocol
SAML	Security Assertion Markup Language
SEM	Smart Evacuation Management
SIM	Subscriber Identity Module

SIP	Session Initiation Protocol
SNR	Signal-to-noise ratio
VCs	Verifiable Credentials
VNF	Virtual Network Functions
UE	User Equipment
webRTC	Web Real-Time Communication
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network
WP	Work Package
XMPP	Extensible Messaging and Presence Protocol

Executive Summary

Ensuring the safety of passengers during maritime accidents is directly linked to effective ship evacuation procedures. While numerous strategies for mitigating casualties have been explored by the maritime safety research community in recent years, digitising and automating the evacuation process remains a challenging task.

As part of the PALAEMON project, the Passenger Mustering and Evacuation Process Automation System (PaMEAS) aims to develop a technology-assisted evacuation management approach and demonstrate its effectiveness in real-world scenarios. The goal of the PaMEAS system is to showcase a smart evacuation process that leverages advanced technologies such as indoor localization techniques, integration of passenger location with their identity (while preserving privacy), real-time personalised notifications to guide passengers, and a 5G Standalone network deployed specifically for this project to deliver alerts and notifications with low latency.

This report provides a comprehensive short description of the integrations of the PaMEAS System, between the different components of PaMEAS (PaMEAS-Applications, PaMEAS-Wireless and PaMEAS-Cell), with other components of the PALAEMON ICT Ecosystem (Database Later, PALAEMON Incident Management Module, Risk Management System etc.), in general, between hardware and software components,

1. Introduction

The present document is the Deliverable D5.16 “PaMEAS hardware and software components integration (v2)” of the PALAEMON project. The deliverable D5.16 is a part of the WP5 of PALAEMON which is entitled as “PALAEMON on-board mustering tools and services” / Task 5.4 “PaMEAS - Passengers Mustering and Evacuation Process Automation System” (led by the University of the Aegean; Ericsson Hellas, Athonet and DNV GL Hellas complete the group of project partners participating in this Task). D5.16 includes also the essential of the Version 1 (V1) of this Deliverable (D5.15) which could not be delivered at M18 of the project, since the network infrastructures of the project (PaMEAS-W and PaMEAS-Cell) were available only at a very primitive level. It became possible to integrate all the components of PaMEAS, only after the second extension of the project duration (M42-M44) which allows for the “production” deployment of the PaMEAS infrastructures on the relevant “industrial environment” (on a passenger shop).

The PaMEAS software suite is a comprehensive system of application and network components, incorporating both open-source and commercial components. Its purpose is to provide "ICT intelligence" and a degree of automation to support the ship evacuation process, covering the entire process from activating the evacuation plan to using life-saving equipment and clearing the ship.

The integration of PaMEAS was a key aspect of Task 5.4. Deliverable D5.16, PaMEAS hardware and software components integration (V2)" is the final deliverable concerning the integration and implementation of the PaMEAS system. D5.16 reports on the effective integration of the PaMEAS system architecture and components already, reported in the relative deliverables (D5.10 [1] , D5.12 [2] , D5.14 [3]), as well as on the integration of PaMEAS with the broader PALAEMON ICT ecosystem. As a result:

- This report provides a short descriptive overview of the integration efforts which took place under Taks 5.4 to ensure the PaMEAS system implemented all the necessary functionality and implemented all the necessary integrations to support the piloting actions of WP8.
- This report overviews the integration efforts executed with respect to the integration of PaMEAS with the rest of the core PALAEMON infrastructure, the integration of PaMEAS with specific modules to create the Smart Evacuation Management platform (SEM) and finally the integration efforts with respect to the infrastructure deployed on the ship.

PaMEAS was progressively integrated with all necessary PALAEMON systems to ensure a fully operational service offering a technology-assisted evacuation management approach. The integrations progressed as the various components were becoming available, with each integration step supporting the testing of a different aspect of PaMEAS. Specifically:

1. The first step enabled the integration of the core PaMEAS functionalities (i.e., the launching a predefined evacuation plan, in case of an emergency, in the form of

rules, standard functions, notification messaging policies and case/incident management that specify how the evacuation process should be conducted) within the PaMEAS-A microservice architecture, as well as the cloud integration of the different environments (application servers) bringing the PaMEAS-A components together and linking PaMEAS with the broader PALAEMON ICT ecosystem.

2. The second step enabled the integration of PaMEAS-A with the indoor positioning infrastructure, i.e., PaMEAS-W - deployed on board of ELYROS F/B (software-hardware integration | work in cooperation with WP8).
3. The third step enabled the complete integration of the PaMEAS system, i.e. the integration of the 5G Standalone Network, PaMEAS-Cell - deployed on board ELYROS F/B (software-hardware integration | work in cooperation with WP8).

Table 1: PaMEAS Integrations

Integration Round	Components Integrated	Result
1st -Baseline Integration -Augmented Integration	• DFB[1] • Evacuation Coordinator[2] • Location Simulator • SRAP[3] • PIMM[4] • Smart Bracelets (SBs)	PaMEAS-A Executable Service
2nd	• PaMEAS-Cell	PaMEAS integrates with PaMEAS-Cell 5G communication network
3rd	• PaMEAS-W	Complete integration of PaMEAS, including PaMEAS-W indoor positioning infrastructure

Specifically, this report is structured in the following sections:

Section 2 provides a short overview of the first round of integrations between the PaMEAS-A microservices and between PaMEAS-A and the rest of the PALAEMON ICT ecosystem components resulting in an executable service.

Section 3 provides a short overview of the second round of integrations between PaMEAS and the 5G Standalone network (PaMEAS-Cell), which is deployed in an “industrial environment”, on a passenger ship, for the needs of the project to implement a high reliability

[1] The Data Fusion Bus (DFB) implements a message queue between all PALAEMON services
[2] The Evacuation Coordinator module broadcasts any changes to the ships evacuation status all PALAEMON components
[3] The Smart Risk Assessment (SRAP) module calculates risks about the health conditions of the passengers and the overall process of the evacuation
[4] The Passenger Incident Module (PIMM) implements the Bridge Dashboard user interface of PALAEMON

and low latency communication channel between the Bridge, the land-based control authorities, the passengers and the crew.

Section 4 provides a short overview of the third round of integrations between PaMEAS, PaMEAS-Cell and PaMEAS-W, the Wireless network, deployed on the same passenger ship, to support the people location sensing and tracking capabilities of PaMEAS (for the passengers and crew members).

2. PaMEAS 1st Round of Integration

This section briefly overviews the first round of integrations of PaMEAS which resulted in the creation of an executable service implementing all necessary evacuation management flows.

Table 2: PaMEAS 1st round of Integrations

Integration Round	Components Integrated	Result
-Baseline Integration -Augmented Integration	● PaMEAS-A microservices ● With PALAEMON Core ICT: ○ DFB ○ Evacuation Coordinator ○ Location Simulator ● With other PALAEMON Services ○ SRAP ○ PIMM ○ etc.	PaMEAS Executable Service

2.1 PaMEAS-A Baseline Integration (internal microservice integration and Integration with the core services of the broader PALAEMON ICT ecosystem)

The PaMEAS Software Suite (PaMEAS-A) is a collection of microservices that work together to provide specific functionalities, organised into high-level components. PaMEAS-A components are further divided into the following major groups operating through Application Program Interfaces (APIs):

Processing Components:

1. People Management System (PMS) - C1
2. PALAEMON Mobile Apps - C2
3. PaMEAS Evacuation Enabler - C4
4. PALAEMON Emergency Messaging Service - C5
5. PaMEAS Incident Manager - C6

Integration Components:

6. PaMEAS Access Manager - C3
7. PaMEAS-SRAP Integrator - C7
8. PaMEAS Passenger Location Simulator - C8

The functionality of each of these high level components is implemented via the integration of several PaMEAS-A microservices, each microservice implementing specific features. As a result, this architecture enables PaMEAS-A services to operate on the premises of sole responsibility offering better maintainability and integration flexibility, significantly simplifying the integration with other software and hardware systems. In fact, PaMEAS-A microservices expose REST APIs (following the OpenAPI[5] specification ensuring ease of integration) via which other services can query for data or initiate flows. Furthermore, authorization to these REST APIs is secured using OAuth2.0 resource server flows[6] ensuring fine grained access control policies.

The integration work at this stage (1st Round - Baseline Integration) underwent four revisions:

First, the microservices of PaMEAS-A (both processing and integration components) were integrated using the aforementioned REST APIs.

Second, the internally integrated PaMEAS-A architecture extends to include the common messaging layer of the PALAEMON ICT ecosystem. The PALAEMON ecosystem implements a core communication platform between all modules called the **Data Fusion Bus (DFB)**. The DFB creates a message queue between all PALAEMON services enabling service to service communication via predefined messages and is defined in D2.7 [1]. This implementation is based on the deployment of a Kafka[7] instance with specific topics being defined for each type of communication between the components.

PaMEAS-A integrates with the DFB service which acts as:

- the **message queue** between PaMEAS and the rest of the PALAEMON ecosystem modules. The PaMEAS Orchestrator reads the outputs of all relevant PALAEMON Data from their respective DFB Kafka topics, processes them and triggers the respective PaMEAS flows. For example when the ships evacuation status changes to “Mustering” the Orchestrator will trigger the flow to generate and transmit to the users devices the appropriate mustering instructions. Furthermore, the PaMEAS Orchestrator publishes events on a dedicated Kafka topic that any authorised PALAEMON ecosystem service can read.
- the **persistence layer** of PaMEAS. Specifically, the Elasticsearch instance of the DFB is used by the DB Proxy component of PaMEAS to persits all PaMEAS related data[8]

[5] https://swagger.io/specification/
[6] https://www.oauth.com/oauth2-servers/the-resource-server/
[7] https://kafka.apache.org
[8] all personal identification information of the passengers and crew members are stored encrypted.

Integration takes place over a REST API (between the DBProxy service and the Elasticsearch instance of DFB) and over Kafka Streams[9] (for the integration of the PaMEAS Orchestrator and the Kafka instance of DFB), as shown in Figure 1.

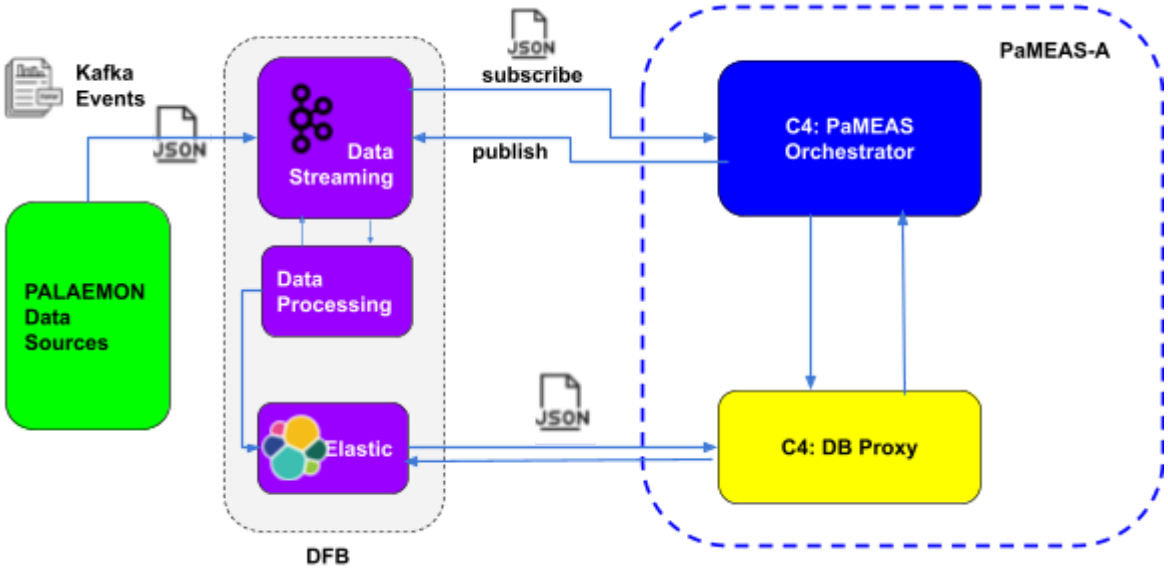

Figure 1: PaMEAS-A & DFB Integration

Third, the PALAEMON ecosystem maintains a collective state, shared between all PALAEMON modules, corresponding to the evacuation states of the vessel as defined by PALAEMON (Figure 3).

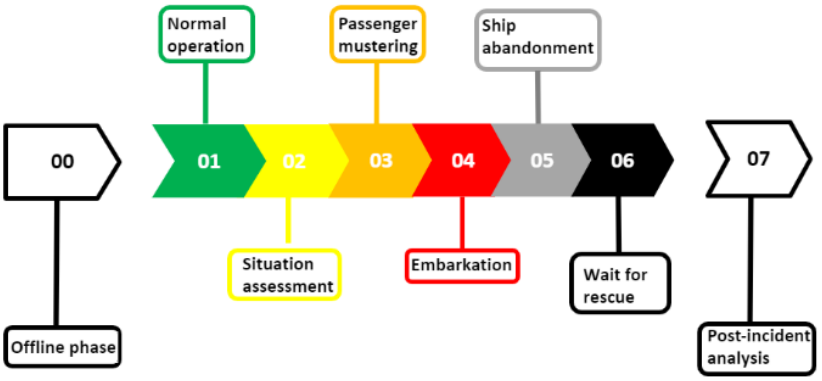

Figure 2: Maritime Emergency Evacuation states defined by PALAEMON

[9] Kafka uses a binary protocol over TCP for streaming data on topics. Kafka Streams is an abstraction over producers and consumers that lets you process your Kafka data in a declarative way. https://kafka.apache.org/protocol

The PALAEMON ICT module responsible for maintaining and broadcasting the evacuation status of the vessel is the **Evacuation Coordinator**. Specifically, the Evacuation Coordinator broadcasts any changes to the ships evacuation status (as those are made by the Bridge) to a specific Kafka topic ("evacuation-coordinator"). Integration between PaMEAS and the Evacuation Coordinator module is implemented as presented in Figure 3.

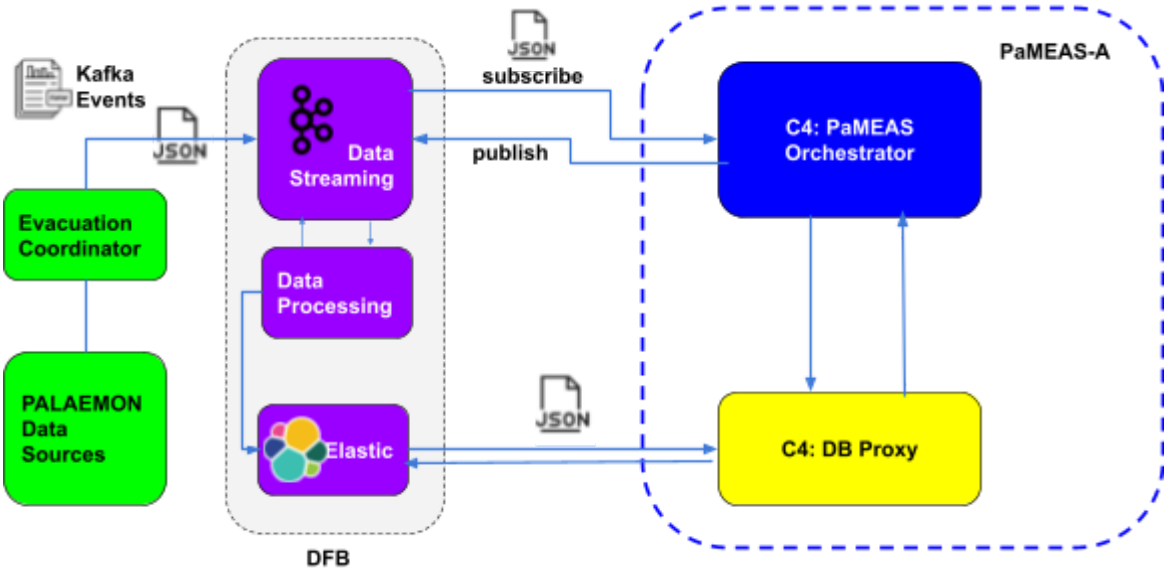

Figure 3: PaMEAS-A & Evacuation Coordinator Integration

The PaMEAS-A integration with the DFB and the Evacuation Coordinator makes the system operational. However, since this integration took place before any network (PaMEAS-W or PaMEAS-Cell) integrations were implemented, synthetic data of passenger and crew locations were necessary to provide an executable service. For this reason, PaMEAS, finally, implemented (and integrated) component **C8: PaMEAS Passenger Location Simulator module**. This module mimics the behaviour of a Real Time Location System (RTLS) generating "virtual" passenger locations and movement on the interior of the ship. The PaMEAS Location Simulator service integrates with the rest of the PaMEAS-A module by posting these data to the PaMEAS RTL API Manager microservice[10], using a secure REST API (integration illustrated in Figure 4)[11].

[10] This module abstracts the specifics of the RTLS system employed enabling the integration of different such solutions to PaMEAS with minimal integration effort and ensuring the changes do not cascade into the rest of the microservices implementing the platform.
[11] We assume an interconnection with the 4G public network, necessary to obtain an end-to-end system functionality.

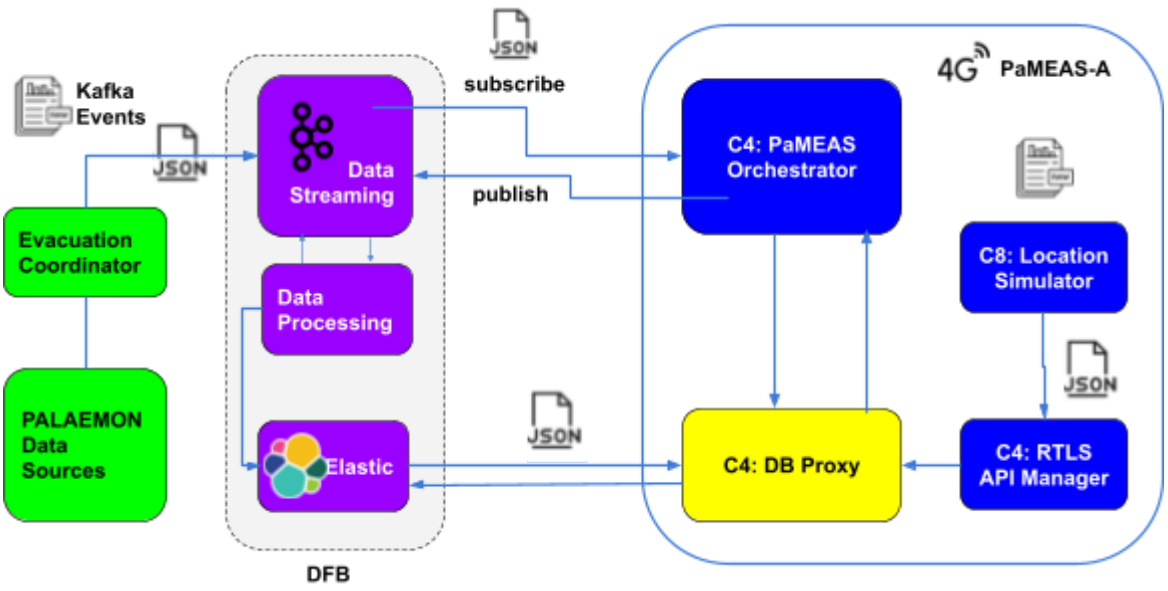

Figure 4: PaMEAS-A & DFB & Evacuation Coordinator & Location Simulator Integrations

As a result, **all of the defined emergency evacuation flows of PaMEAS-A can be executed** using all of the aforementioned integrations (PaMEAS-A & DFB & Evacuation Coordinator & Location Simulator).

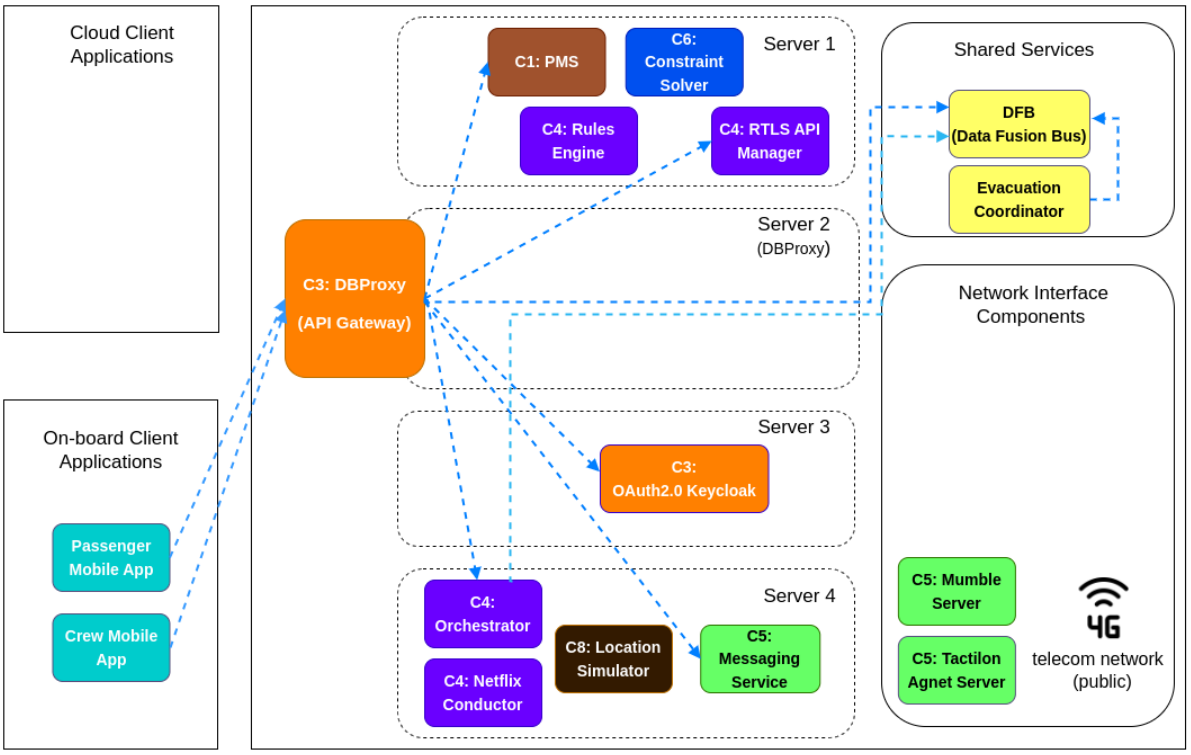

Figure 5: PaMEAS Baseline Integration

2.2 PaMEAS Augmented Integration with the broader PALAEMON ICT ecosystem

PaMEAS-A complements its functionalities by integrating with additional PALAEMON ICT modules. Specifically, PaMEAS-A integrates with:

- The Smart Risk Assessment (SRAP)
- The Passenger Incident Module (PIMM)
- The PALAEMON Smart Bracelets

The **SRAP** module calculates risks about the health conditions of the passengers and the overall process of the evacuation. Integration between PaMEAS and SRAP is implemented as follows (two ways of integration):

- SRAP consumes anonymized passenger location data and biometrics to evaluate the risks of the passengers facing an health emergency by connecting to PaMEAS-A (People Management System) over a REST API.
- PaMEAS consumes the outcomes of SRAP (via the PaMEAS-SRAP Integrator, which is part of the PaMEAS Orchestrator microservice), published on the message queue, and in case a passenger health emergency is detected, initiates the appropriate incident management flows.

PIMM is an independent component of the PALAEMON ICT ecosystem, implementing the Bridge Dashboard User Interface functionality. Specifically, the integration between PaMEAS and PIMM enables visualisation UIs for the location of the passengers and crew members and about the progression of the mustering process (generated by PaMEAS). Moreover, it triggers, via appropriate UIs, the update of the ships Evacuation Status integrating with the Evacuation Coordinator module. PIMM is integrated with PaMEAS as follows:

- Fetches the location informαtιov of the passengers and crew members in real time and visualises it (over a REST API).
- Fetches information about the progression of the mustering per muster station in real time and visualises it (over a REST API).
- Enables the triggering of PaMEAS flows via:
    - Indirectly: Integration with the Evacuation Coordinator (over Kafka streams).
    - Directly: Integration using the Orchestrator module for the assignment of crew members to passengers issues (over a REST API).

The PALAEMON **Smart Bracelets** generate biometric data about the health conditions of the passengers and crew members. Additionally, the Smart Bracelets enable the wearer to manually request emergency assistance by tapping a button on the bracelet. The biometric data and the requests for help are streamed to PALAEMON using the DFB. PaMEAS integrates with the Smart Bracelets component by registering to these DFB topics (over Kafka streams).

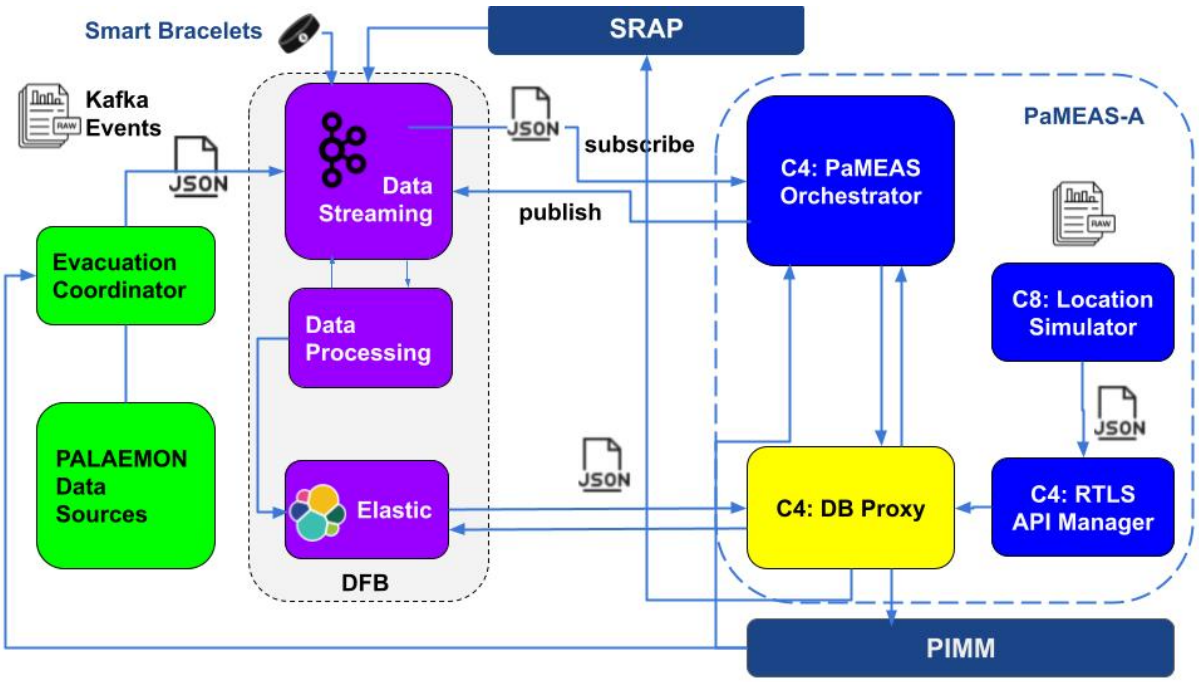

Figure 6: PaMEAS DFB, Evacuation Coordinator, SRAP, SB, PIMM and Location Simulator Integrations

The described integration of PaMEAS with the DFB, the Evacuation coordinator, the Location Simulator, SRAP, PIMM and the Smart Bracelets generates a fully executable service[12] via which it is possible to verify the capacity of PaMEAS to execute the Evacuation Management flows deriving from the design requirements, as those were defined in D2.5 [5] & D2.7 [4].

A **Demonstrator** of the proper integration of PaMEAS with the DFB, the Evacuation coordinator, the Location Simulator, SRAP, PIMM and the Smart Bracelets is available online and reported in detail in D5.14 (PaMEAS Software Suite_Deployment V2):

- D5.14 - Section 4
- Video presentation: https://youtu.be/J7uQ0PfI8pk

[12] A report of a Technology Readiness Level (TRL) 4 of the functionality of PaMEAS-A implemented over the presented integration is available in D5.14 [3]

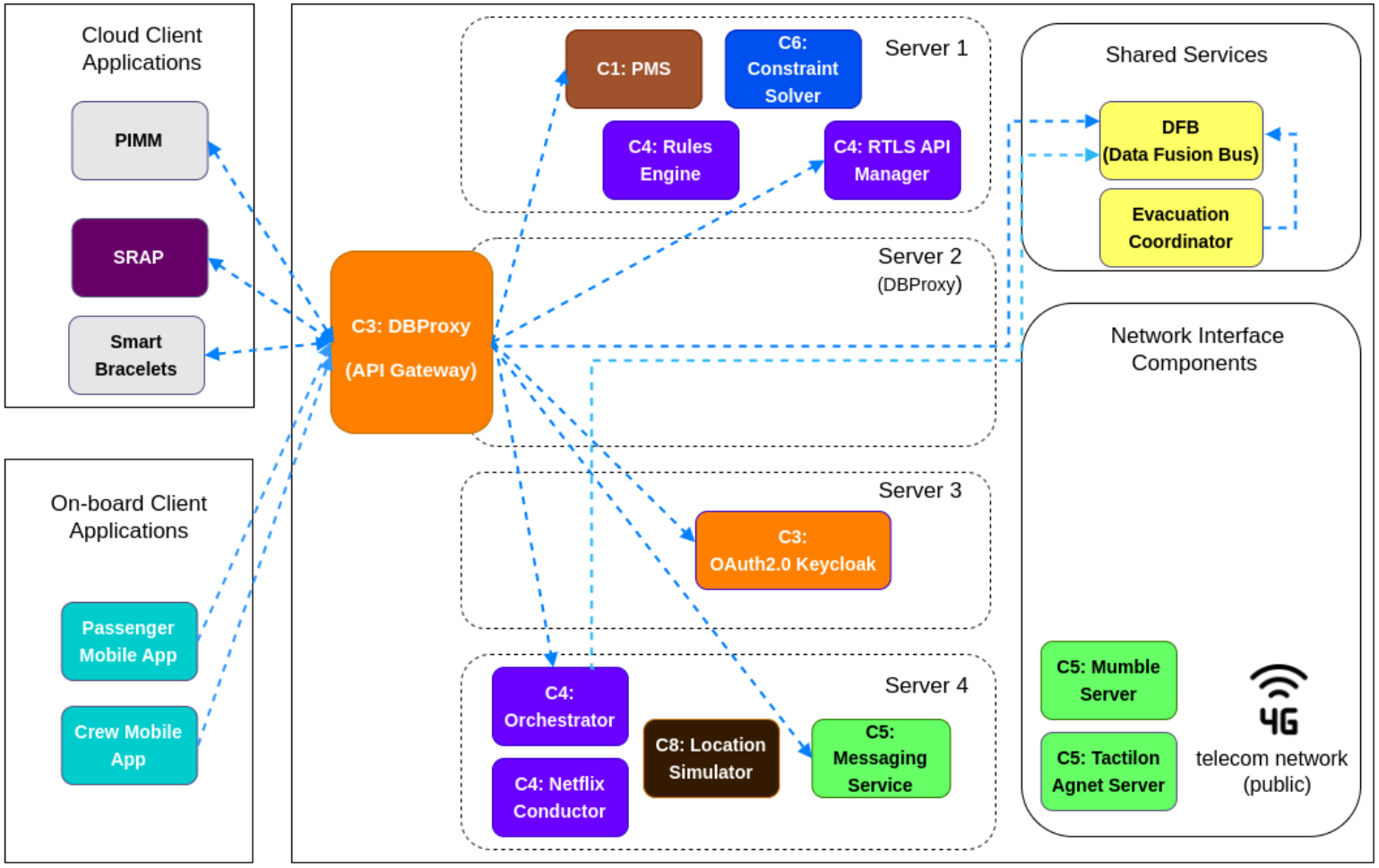

Figure 7: PaMEAS - End of Integration Round 1 (Augmentred Integration)

3. PaMEAS integration with PaMEAS-Cell (Software-Hardware Integration)

This section briefly overviews the second round of integrations of PaMEAS which resulted in the interconnection with a 5G Standalone network (PaMEAS-Cell).

Table 3: PaMEAS 2nd round of Integrations

Integration Round	Components Integrated	Result
2rd	• PaMEAS-Cell	Integration of PaMEAS with the 5G communication network (PaMEAS-Cell)

PaMEAS-Cell was designed as a Private 5G Standalone Network which satisfies the prerequisites and requirements of the project in terms of coverage, performance, latency, security, and reliability necessary for evacuation procedures (D5.10 [1]). Passengers and crew members use 5G enabled mobile devices to register to the PaMEAS-CELL 5G SA network and are provided with connectivity.

Specifically, the PaMEAS-Cell network is used to:

- Deliver alerts, warnings and personalised notifications to passengers with low latency performance and reliability - and collect feedback from passengers and crew (i.e. reactions such as confirmation of reception etc., requests for help, personal health data in the case of an accident etc.)
- Manage and drive crew to their assigned tasks and coordinate crew members via messaging and direct audio and video streams.

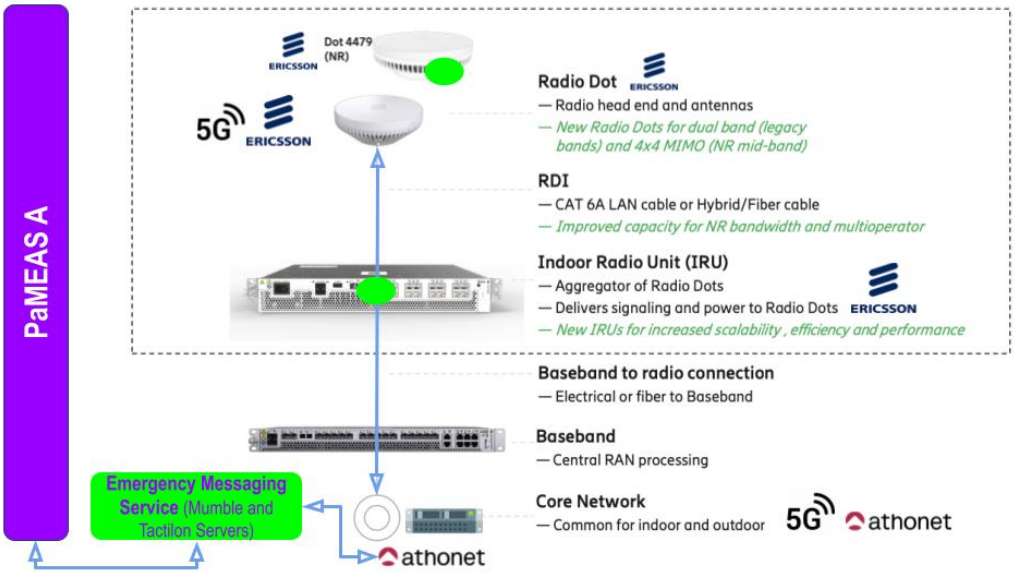

Figure 8: PaMEAS-Cell architecture

The **key integration component** between PaMEAS-A and PaMEAS-Cell is the PALAEMON **Emergency Messaging Service**. This PaMEAS-A component is responsible for the transmission of emergency notifications and alerts to the devices of the passengers and crew members. Furthermore it enables the creation of direct multimedia channels (voice/video) between the bridge and the crew and passengers. The functionality of the Emergency Messaging Service is connected to **PaMEAS Cell 5G Core Module** via the two following modules (connected to 5G Core Module via IP):

- **Mumble Server**: The PaMEAS Mumble Server is an instance of Mumble[13] deployed for the needs of communicating with the passengers. Mumble is a free, open source, low latency, high quality voice chat application and protocol.
- **Tactilon Agnet Work Server**: Airbus Tactilon Agnet is a MCPTT (Mission Critical Push-To-Talk) communication platform that provides voice, video, multimedia services for mission-critical users. It allows secure and reliable transmission of data to all relevant parties. It is used by public safety, fire brigade, airport and industrial users[14].

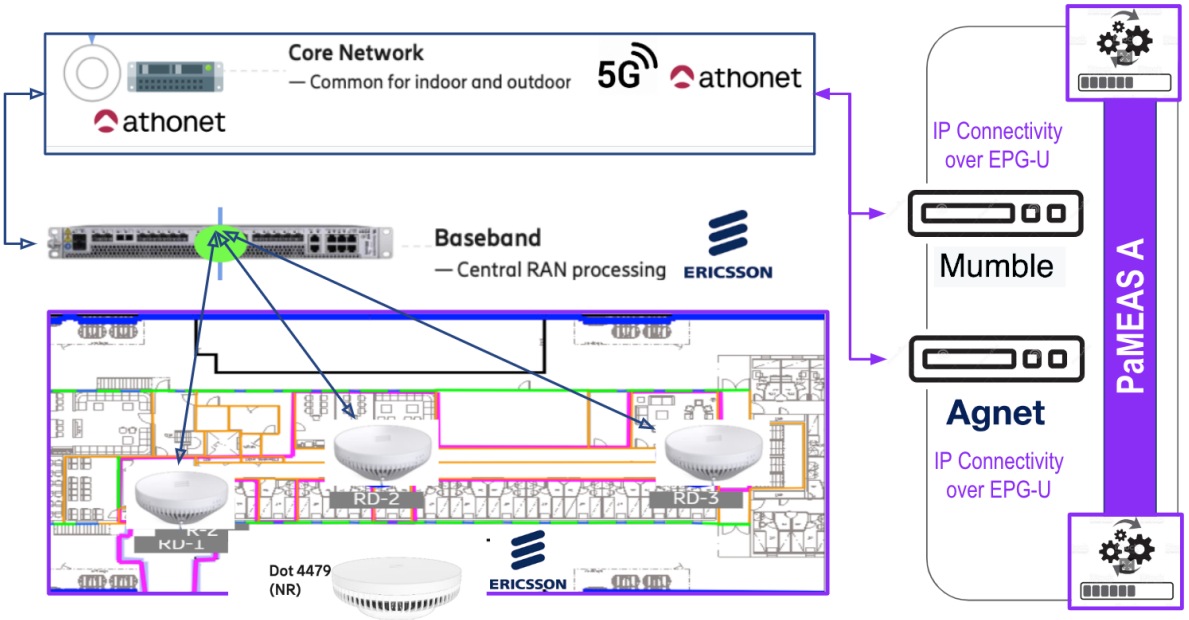

Figure 9: PaMEAS-A & PaMEAS-Cell Software-Hardware Integration

[13] https://www.mumble.info/
[14] https://www.securelandcommunications.com/agnet
https://www.timesaerospace.aero/news/airports/india-public-safety-users-to-receive-airbus-tactilon-agnet-solution

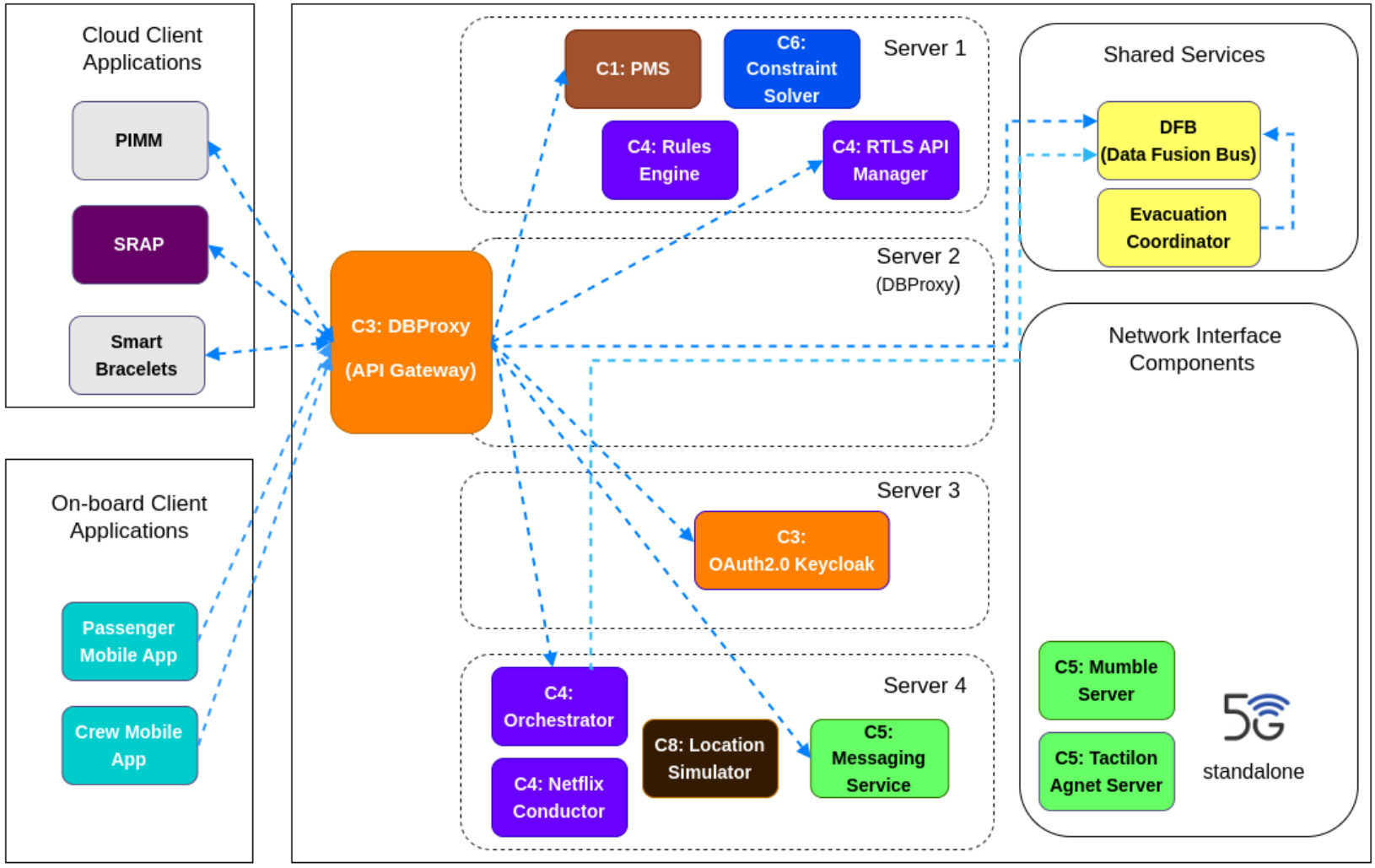

Figure 10: PaMEAS - End of Integration Round 2

4. PaMEAS integration with PaMEAS-Cell and PaMEAS-W (Software-Hardware Integration)

This section briefly overviews the third and final round of integrations of PaMEAS which resulted in the creation of a complete service implementing all necessary evacuation management flows, offering indoor positioning over PaMEAS-W and integrated interconnection with a high reliability low latency messaging 5G Standalone network (PaMEAS-Cell).

Table 4: PaMEAS 3rd round of Integrations

Integration Round	Components Integrated	Result
3rd	• PaMEAS-W	Complete integration of PaMEAS, including PaMEAS-W indoor positioning infrastructure

PaMEAS-W deploys **Wi-Fi 6 Access Points (APs**) and **BLE networks** that are used as the primary source of indoor positioning data for tracking of the passengers and crew members in case of emergency.

The users of this network (i.e. passengers and crew members) can connect their mobile phones with the PALAEMON passenger and crew apps over PaMEAS-Cell. These apps integrates with the PaMEAS-W networks by using the signals of both the Wi-Fi 6 APs and BLE network to calculate in real time the location of the user within the premises of the ship, and transmits this information to the back end of the RTLS service (deployed on the cloud or in the premises of the ship). The transmitted information contains a timestamp, the x and y coordinates of the user, the floor (deck) they are in and information about the device of the user[15].

[15] The information transmitted might vary between the different RTLS services, but all such services offer a timestamp, the x,y coordinates and an identifier for the device of the user.

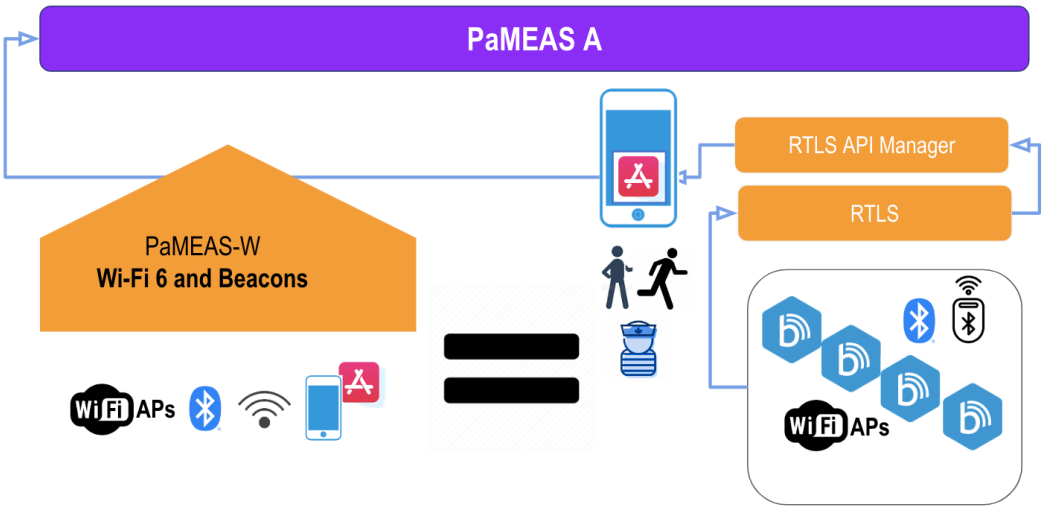

Figure 11: PaMEAS-W architecture

PaMEAS adopts the concept of a Real Time Location Service as-a-service (RTLS-SaaS) by implementing the RTLS API Manager microservice which abstracts the actual implementation of the RTLS system. The RTLS API manager:

- Periodically fetches the location data from the RTLS service
- Transforms them into a PaMEAS specific data model[16]
- Updates the profiles of the passengers and crew members, making this information available to the rest of the authorised PaMEAS services.

As a result the RTLS system, similarly to 5G network infrastructure, becomes a plug-and-play feature of PaMEAS enabling the best suited system to be used depending on the specifics of each vessel, and furthermore enabling the deployment of the RTLS service either on the cloud or on-premises of the ship .Integration of the PaMEAS RTLS API Manager microservice and the RTLS service is implemented over a REST API (although different RTLS services may require different integrations, e.g. over grPC protocol).

[16] The PaMEAS Location Data model unifies and enhances the information received by the RTLS system including geofencing information. If such information is not provided by the RTLS service it is calculated by the RTLS API manager service is real time.

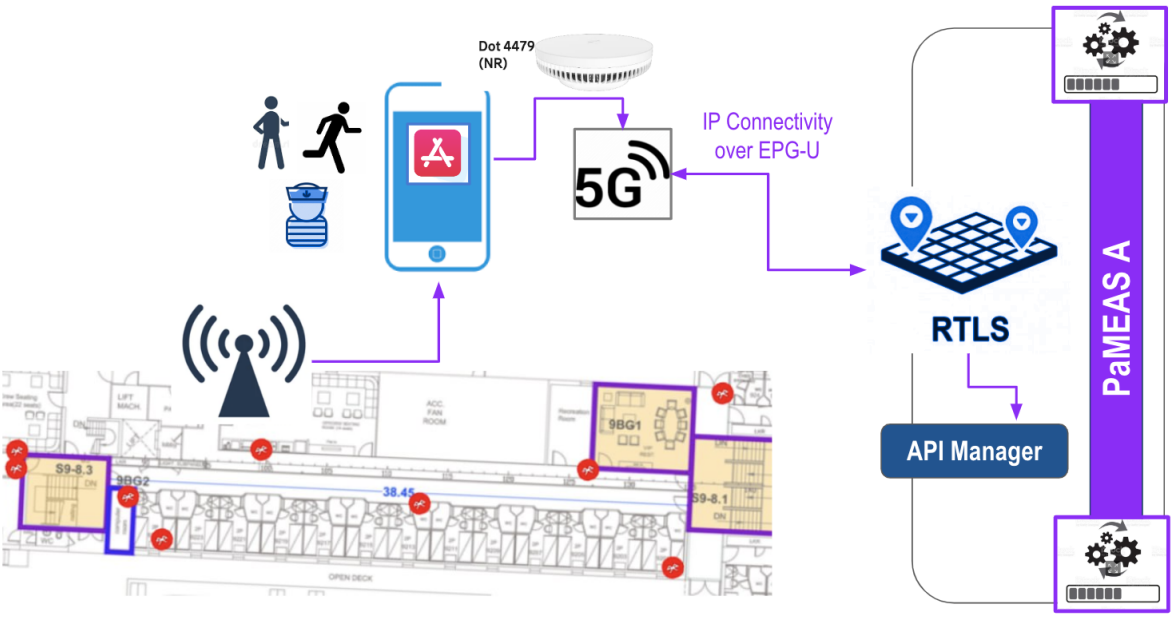

Figure 12: PaMEAS-A & PaMEAS-W Software-Hardware Integration

A **Demonstrator** of the complete integration of PaMEAS, including PaMEAS-W indoor positioning and PaMEAS-Cell infrastructure is available online and reported in detail in D5.14 (PaMEAS Software Suite_Deployment V2):

- D5.14 - Section 4
- Video presentation: https://youtu.be/HooVWFkStqM

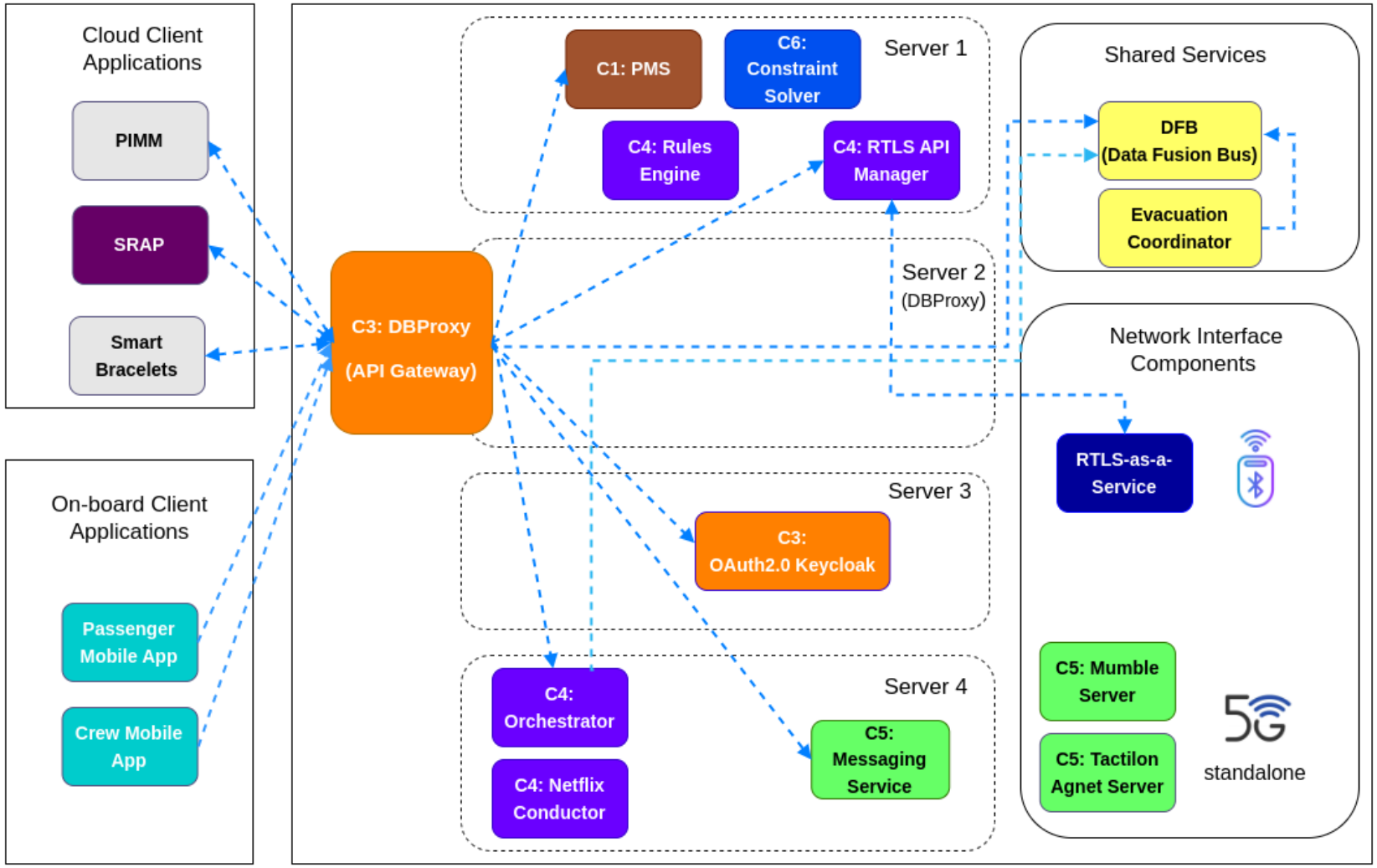

Figure 13: End of Integration Round 3

5 References

[1]. PALAEMON D5.10 “PaMEAS design principles and Technical Architecture (V2)”
[2]. PALAEMON D5.12 “Ship Radio Dot System: design and deployment (V2)”
[3]. PALAEMON D5.14 “PaMEAS Software Suite: Deployment (V2)”
[4]. PALAEMON D2.7 “PALAEMON Architecture (V2)”
[5]. PALAEMON D2.5 “Final version of PALAEMON Use Cases Definition & Operational Requirements ”