PROJECT DELIVERABLE REPORT

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

D5.10 PaMEAS design principles and Technical Architecture (V2)

A holistic passenger ship evacuation and rescue ecosystem

MG-2-2-2018

Marine Accident Response

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0.3	10/07/2022	UAegean	2nd version of Deliverable
0.4	20/12/2022	UAegean	Further additions
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1.0	30/03/203	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 accidents is directly linked to the effectiveness of ship evacuation procedures. While various methods to minimise casualties have been proposed and studied in recent years, digitising and automating the evacuation process remains a significant challenge. The PaMEAS system, developed as part of the PALAEMON project, aims to address this challenge by implementing a technology-assisted evacuation management approach and demonstrating its effectiveness in real-world scenarios.

This document, D5.10 “PaMEAS design principles and Technical Architecture (v2)”, presents the refinements and updates made to the initial Technical Architecture of PaMEAS reported in D5.9 “PaMEAS design principles and Technical Architecture (v1)” of the PALAEMON project. The resulting final version of the PaMEAS architecture will be deployed (D5.14) and utilised to support the piloting actions of the project (WP8).

1. Introduction

The present document is the Deliverable D5.10 “PaMEAS Design Principles and Technical Architecture (v2)” of the PALAEMON project. The deliverable D5.10 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).

PaMEAS software suite is a multi-layered system of applications and network functionality, using both open source and commercial components, which supports the ship evacuation process with “ICT intelligence”, and a certain degree of automation. Its functionality should cover the whole evacuation process from the activation of the Evacuation Plan until the use of the Life Saving Appliances and the clear of the ship.

The design of PaMEAS was one of the important issues of Task 5.4. The Deliverable D5.9, “PaMEAS design principles and Technical Architecture (V1)” [1], has initially formulated the design requirements, design principles and system architecture design for this essential PALAEMON component. D5.10, this Deliverable, reports on the updates made to the original design principles and technical architecture presented under D5.9, to ensure that the system will be able to support the piloting efforts of WP8 by providing the ability to identify passengers and seafarers' location within the ship and provide location-based safety and evacuation services with the following features:

1. High accuracy indoor tracking functionality
2. Effective passenger navigation in emergency situations
3. Location analytics, passengers mustering and support to evacuation-rescue services (during a rescue operation, PaMEAS System might be used by the dispatched rescue forces to search and find survivors, promptly approach and rapidly assist them).

Specifically, in D5.9 the initial design of PaMEAS, the key features and required functionalities of the PALAEMON technology-assisted evacuation management approach were presented. The designed architecture covered the Network and Application layers and included various technology building blocks such as microservices, hybrid 4G LTE/5G mobile network, Wi-Fi Access Points (APs), beacons etc. Furthermore, D5.9 described the PaMEAS system architecture design, taking into account proposed use cases, high-level and system requirements, and privacy considerations. After reviewing various technologies, D5.9 provided a comprehensive overview of the PaMEAS architecture and equipment to be used, along with specification and implementation considerations. The architecture presented was aligned with the work being carried out in various WPs and served as the starting point for the actual implementation.

This report updates and refines the starting PaMEAS architecture (V1), as presented in D5.9, and provides its definitive version. Specifically, this report is structured in the following sections:

Section 2 provides an overview of PaMEAS and its design methodology and reports on any updates to PaMEAS to System Design Requirements and Principles.

Section 3 provides an update on the PaMEAS Network architecture, i.e. PaMEAS-W(ireless) and PaMEAS-Cell specifically.

Section 4 presents the final architecture of PaMEAS, including the organisation of the application layer of PaMEAS, i.e., PaMEAS-A.

Section 5 specifically reports on the elements of PaMEAS technical architecture that supports location data privacy and, more generally, offers privacy safeguards in managing passengers; personal information.

2. PaMEAS Design Requirements and Methodology

PALAEMON has progressively developed a technology-assisted re-design of the evacuation management process in passenger ships, named Smart Evacuation Management approach. It integrates IT and process management technology, human factors, ship safety processes, and operating procedures. The Passengers Mustering and Evacuation Process Automation System (PaMEAS) implements the core processes of PALAEMON, by:

1. Enabling the tracking and monitoring of passengers' and crew's positions
2. Automatically launching a predefined evacuation plan, in case of an emergency, in the form of rules, standard functions, notification messaging policies and case/incident management[1] that specify how the evacuation process should be conducted, specific evacuation operations streamlined, and what expectations to meet.

[1] Incident management in this context refers to specific issues that might occur involving passengers that hinder their evacuation capabilities and require the intervention of trained crew members to resolve. These issues can range from pre-existing health conditions, to health emergencies or other types of incidents (like the passenger becoming trapped in a specific area).

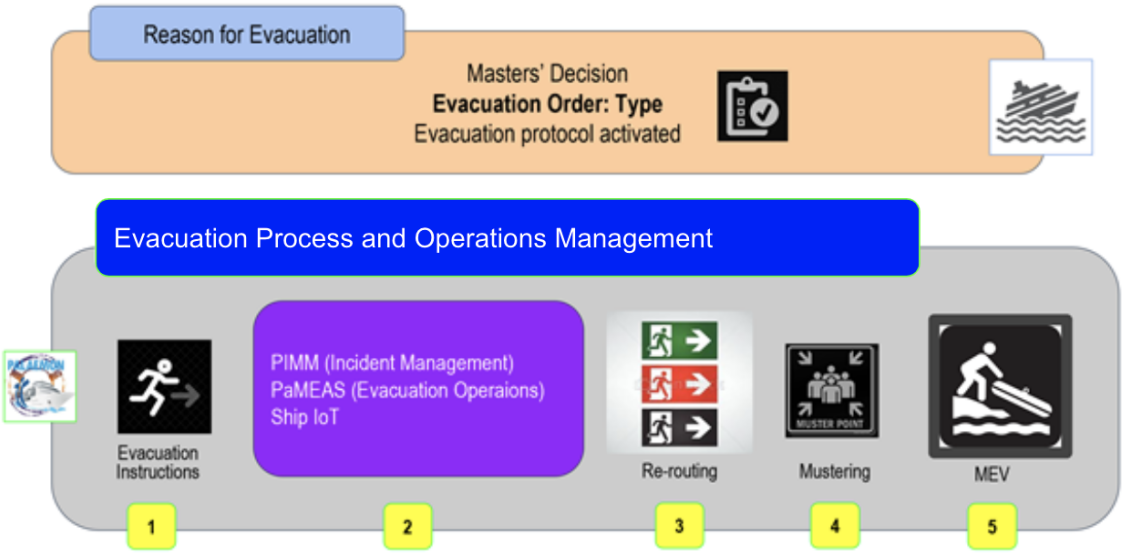

Figure 1: PaMEAS is designed as Process and Operations Management Engine for Ship Evacuation Management

More specifically, PaMEAS has been designed to provide context-accurate and personalised emergency information, issues advice and warnings, and respond to the expectations of the Bridge, crew dispatchers, and other ship personnel, ship companies management etc. PaMEAS also performs incident management functions, such as real-time management of eventual passenger incidents that occur during the evacuation process. Essentially PaMEAS handles the management of the core operations and automation of all Emergency Evacuation states applied by PALAEMON (see Figure 2) in the objective to optimise the evacuation process by providing an "augmented" technology-aided layer of functionality on top of the existing operations and practices.

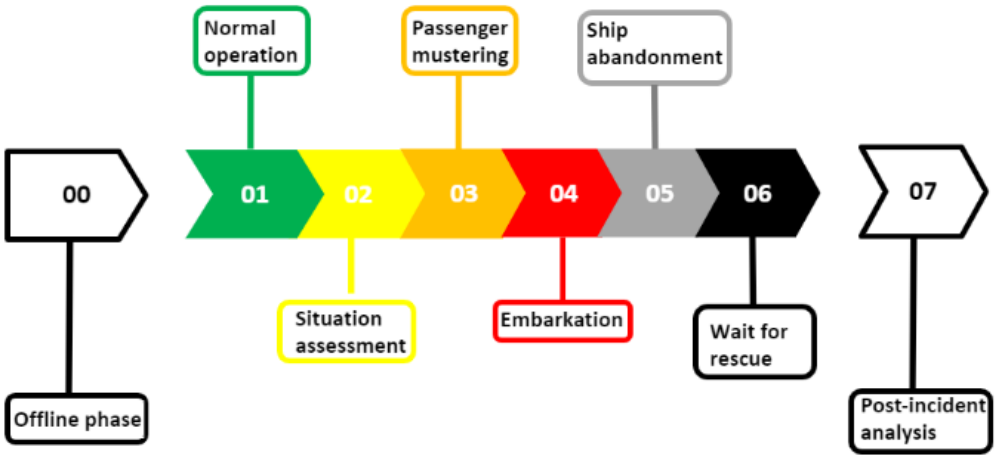

Figure 2: Maritime Emergency Evacuation status flow applied to PALAEMON

The Design Requirements of PaMEAS have not been altered since the previous version of the PaMEAS Design Document (D5.9) and are presented below:

Table 1: PaMEAS initial Design Requirements (list)

PaMEAS Design Requirements
Make real-time adjustments to the Marine Emergency Evacuation response based on passengers' location monitoring
Impact the response's reliability and "evacuability" by providing directions to and through the evacuation paths
Combine advanced passenger traceability with operations management capabilities that allow crew to efficiently be part of the decision loop
Provide sufficient flexibility to cope with the broad range of incidents that may occur during the ship evacuation process

Furthermore, the design methodology of PaMEAS (based on Product-Service System Design - PSS Design[2]) as defined in D5.9 is confirmed in this design update and presented below:

1. Define a set of Core System Design Principles
2. Conduct a state-of-the-art analysis of the technologies for location tracking and positioning in indoor settings which are the key enablers of PaMEAS functionality (to assess the landscape of available opportunities and constraints for designing Indoor Positioning Systems in an evolving networking environment and in an enterprise architecture integration context)
3. Provide a detailed Use Case Analysis to identify the PaMEAS targeted functionality
4. Derive Design Requirements for both the (bottom) network layer and the (upper) application layer of PaMEAS system.

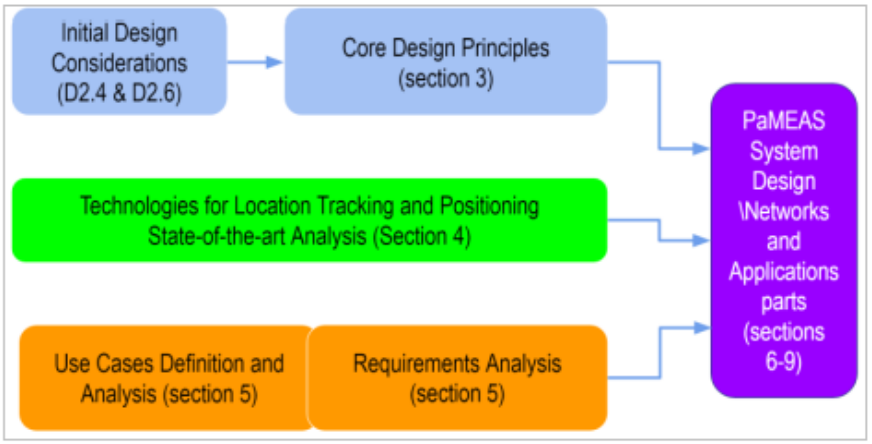

Figure 3: PaMEAS Design Methodology in D.9

[2] https://link.springer.com/book/10.1007/978-1-84882-909-1

This design methodology essentially required an iterative process that should be reapplied if the inputs change over time. Specifically, the original architecture produced using this methodology, and presented in D5.9 the inputs from D2.4 [2] & D2.6 [3], did not change, nor did the analysis of the Use Cases and Requirements presented in D5.9 Section 5. However, the state-of-the-art progressed. This difference in the input elements produced an updated technical architecture (see Table 2).

Table 2: Design Methodology Inputs updates and outputs

Design Methodology Components	Status (no changes or updated)
Design Inputs:	
Design Considerations	no changes
Use Case Definition and Analysis	no changes
Requirement Analysis	no changes
Technologies for Location Tracking and Positioning	updated
Technologies for a low latency/high reliability communications network	updated
Mobile app capabilities	updated
PaMEAS privacy vision	updated
Results:	
PaMEAS-N architecture v2 (PaMEAS Wireless and PaMEAS-Cell)	updated
PaMEAS-A architecture v2	updated

The resulting final PaMEAS Architecture is presented in Figure 4 and 5.

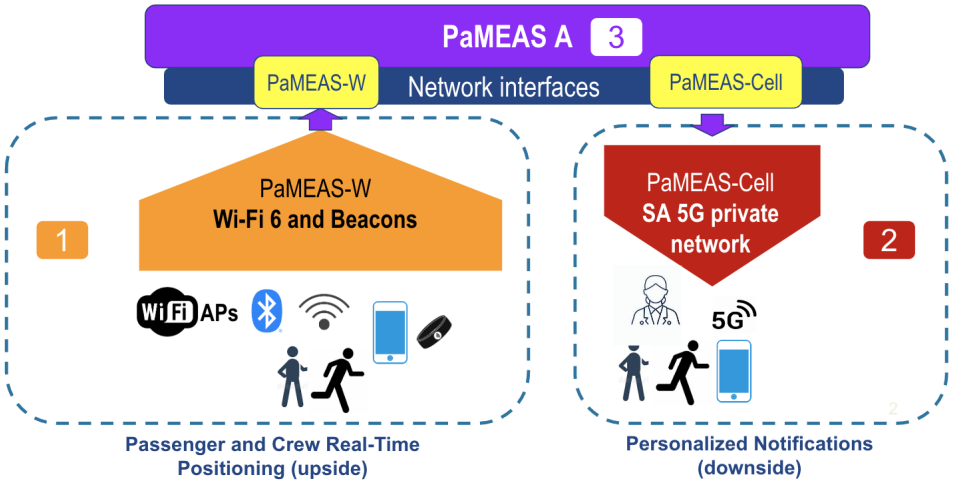

Figure 4: PaMEAS Core Components (final version - V2 | 2023)

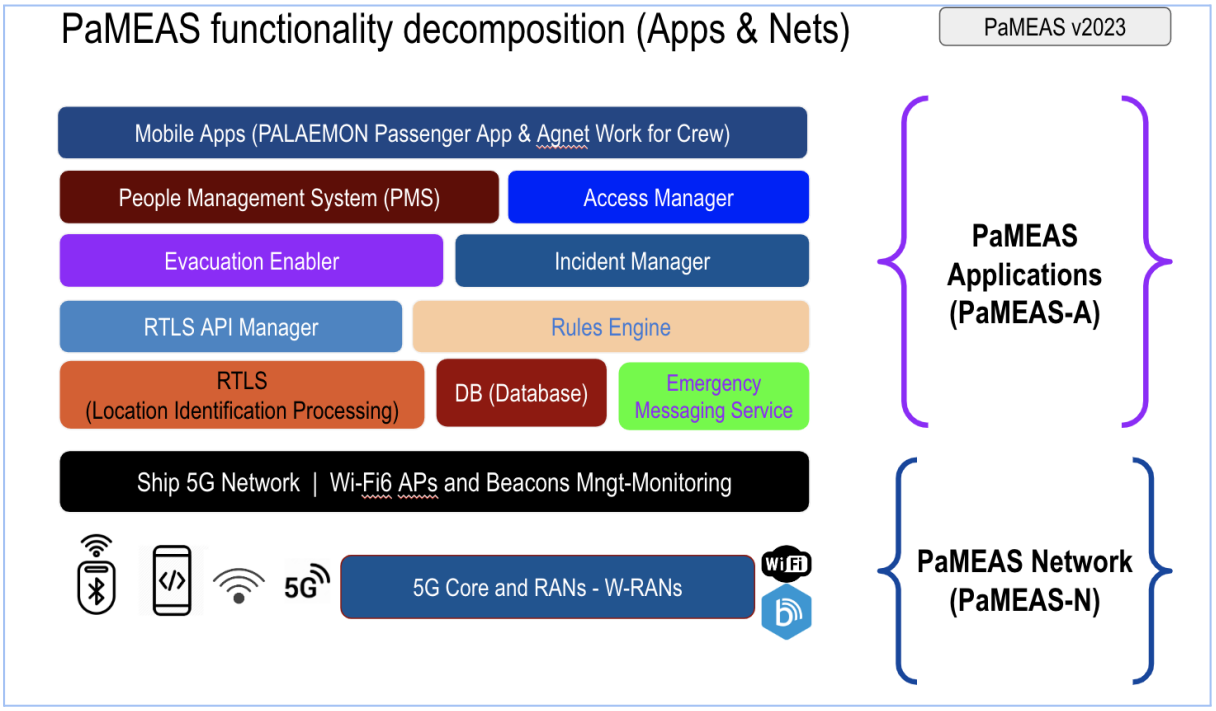

Figure 5: PaMEAS architecture (final version - V2 | 2023)

3 Updated PaMEAS Network architecture

As already explained, the first version of the PaMEAS-N architecture was presented in D5.9. The D5.9 analysis concluded that a 4G LTE-5G solution for the needs of location tracking in industrial and service environments, may not be technically feasible in the short run, at a reasonable cost. For this reason the architecture was partitioned into different network resources: a Wi-Fi & BLE beacon infrastructure for location tracking and a low latency 5G network for emergency communications.

The core premises presented in D5.9 (and as a result the high level architecture of PaMEAS-N) remain unchanged. Specifically, the final architecture of PaMEAS defines two types of networks integrated to provide the necessary functionalities:

- PaMEAS-W: a network of WiFi-6 access points (APs) and Bluetooth Low Energy (BLE) beacons
- PaMEAS-Cell: a low latency 5G network

However, updates in the state of the art and specificities of the pilot environment resulted in targeted updates to details of the implementation of these two networks presented in Table 3.

Table 3: PaMEAS-N Architecture Updates

Technical Architecture Components	Status
PaMEAS-W	Emphasis shift to a Wireless network with less WiFI 6 APs and more BLE beacons for improved indoor positioning service
PaMEAS-N	Upgrade from Hybrid 4G LTE/ 5G to a 5G Standalone Network for increased performance and sustainability
IoT Signage PaMEAS components	Component was deemed essentially obsolete due to the capabilities of the PaMEAS Mobile apps

The PaMEAS-N updated architecture is presented in Figure 5.

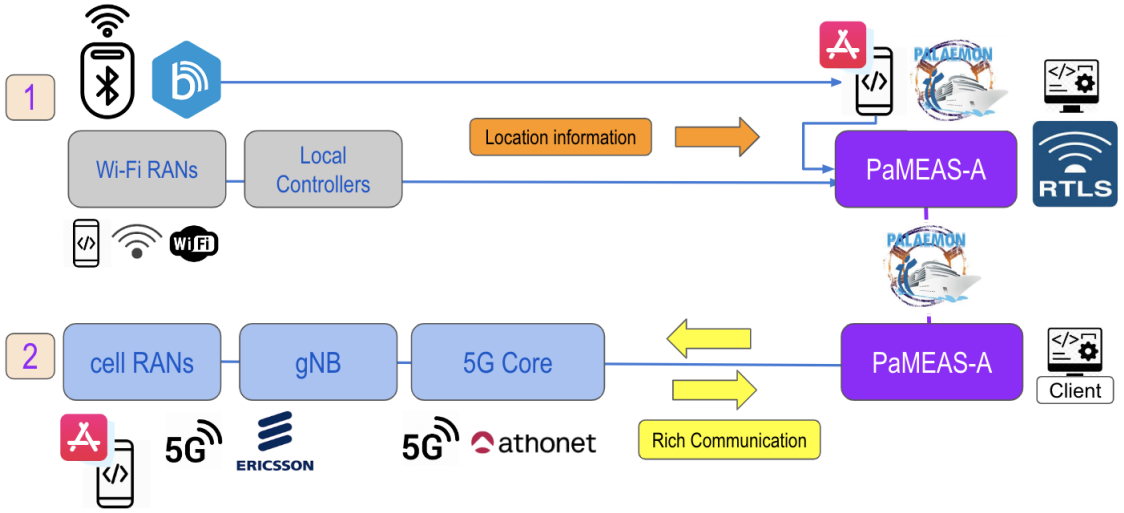

Figure 6: PaMEAS-N Architecture

3.1 Updates in PaMEAS-W

Wi-Fi 6 (IEEE 802.11ax) remains a technology very well suited for indoor positioning systems especially when considering Multiple-Input Multiple-Output Orthogonal Frequency Division Multiplexing (MIMO-OFDM and Angle of Departure (AoD) support. However, during testing on the piloting areas (narrow metal corridors of a ship) it was discovered that the configuration process was extremely time consuming and the WiFi 6 signal, propagated along the surfaces of the metal walls, reduced the accuracy of the produced results.

BLE beacons were originally evaluated as a promising solution but one that suffered from the disadvantage of being shorter in range than that of Wi-Fi. However, again after experimenting, it was observed that due to the nature of the surfaces of the ship the range of the beacons is significantly extended. Additionally, the commercial cost of such beacons is extremely low making this technology of much higher value than originally anticipated.

As a result in the final version of PaMEAS-W both Wi-Fi 6 Access Points (APs) and a BLE networks are used with the BLE beacon network being the primary source of indoor positioning and the Wi-Fi 6 network acting in a complementary fashion to enhance the overall accuracy of the system.

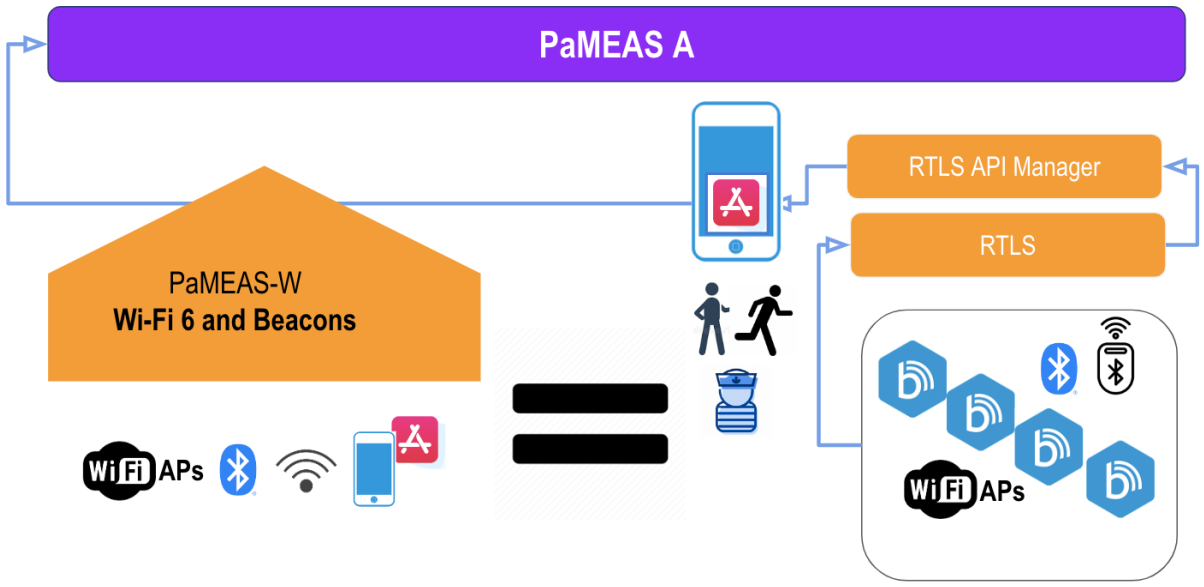

Figure 7: PaMEAS-W architecture

3.2 Updates in PaMEAS-Cell

During the original design of the PaMEAS Technical Architecture it seemed that 5G would need to coexist and interwork with 4G LTE network configurations for many years via non stand-alone deployments (NSA), to reduce time to market and ensure good coverage and mobility. However, the state-of-the-art in this area progressed much faster than anticipated to the point where 5G Standalone (SA) was a much preferable option, especially for industrial environments (public telecom networks may use the 4G LTE - 5G options for smooth transition of the large existing installed bases but this is not a constraint in private networks). 5G Standalone (SA) is an implementation of 5G architecture that solely uses a core network with no dependency on 4G LTE network control function, for data connection and related services (EPC, Evolving Packet Core) and for user data management (UDC, User Data Consolidation), as it happens with the public mobile communications networks, transiting progressively to 5G. 5G SA networks are ultra-low latency and high reliability networks, currently serving the needs of the industry and knowledge-based services for very fast access to higher data rates. For a generic presentation of the issue, see: 5G NR Standalone - network for the future - Ericsson

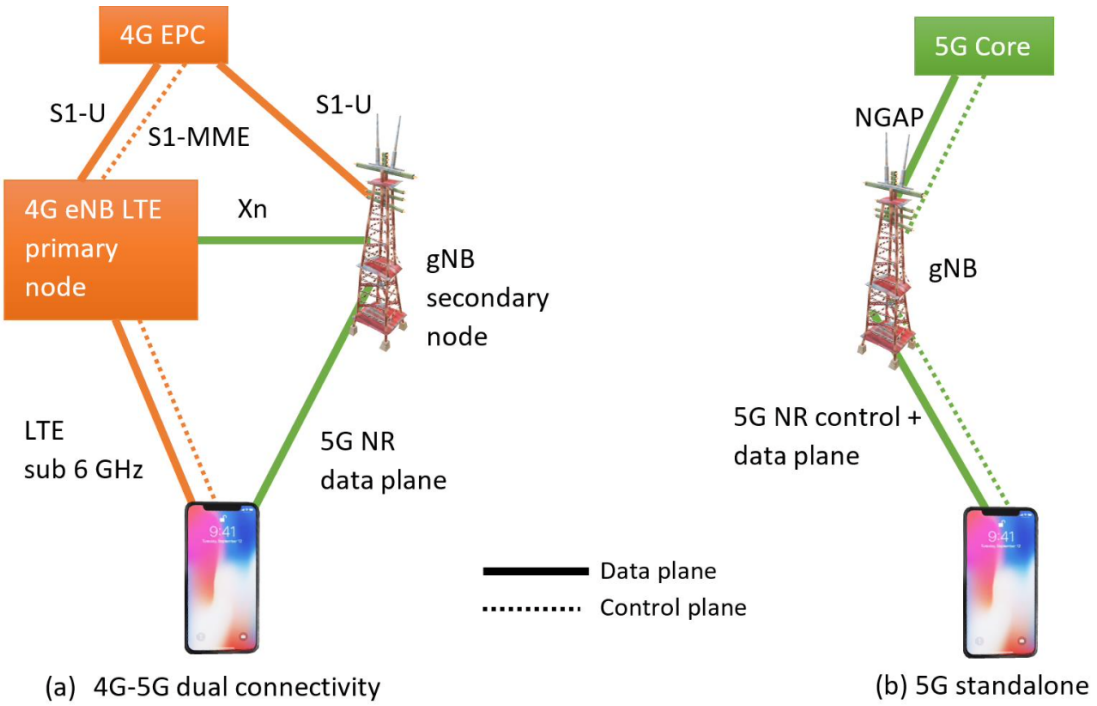

Figure 8: 5G Standalone architecture (b) vs Hybrid architecture (a)

As a result PaMEAS-Cell is designed as a Private 5G Standalone Network which satisfies the prerequisites and requirements of the D5.9 use cases in terms of coverage, performance, latency, security, and reliability necessary for evacuation procedures.

It will be be 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 in the assigned positions and coordinate crew members (i.e. assign tasks) in the case of an issue or an incident taking place during the evacuation of the ship.

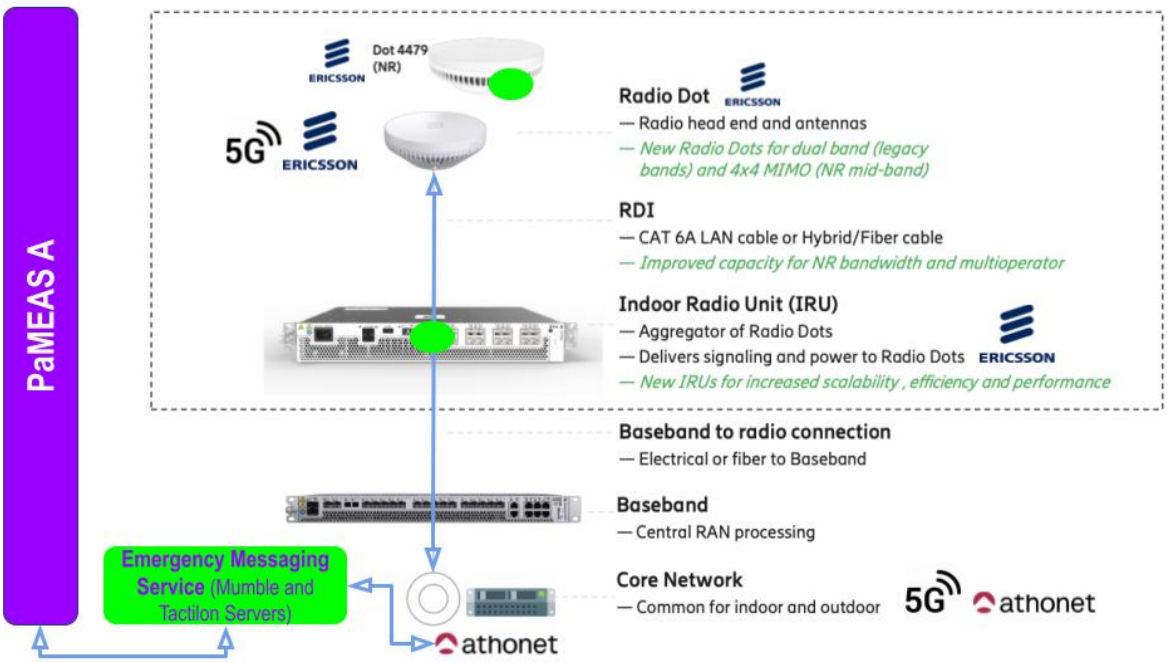

Figure 9: PaMEAS-Cell architecture

3.3 Updates in Signage IoT Network

The first version of the architecture included an IoT network for Evacuation Signalling. However, once the specific technological stack for the PAMEMON Mobile apps was selected it became evident that the apps were the optimal channel to provide the necessary location-based notification and feed the appropriate visual and audible information to the passengers.

However, providing IoT signage information flows simultaneously would complicate the pilot development of the project, in the sense that it would require major modifications in the current structure of the ship where PaMEAS should be deployed. As a result the implementation of mounted signalling devices enhanced by IoT capabilities was discarded as an option. Eventually, there are some advantages and innovation potential from the implementation of IoT Signage facilities, instantly controlled via a 5G network but only newly designed vessels can realistically benefit from this interesting innovation.

4 Updated PaMEAS Applications architecture

The PaMEAS application layer (PaMEAS-A) implements its functionality by defining and integrating a set of microservice. These microservices are clustered into high level components which are further categorised into Procession and Integration.

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

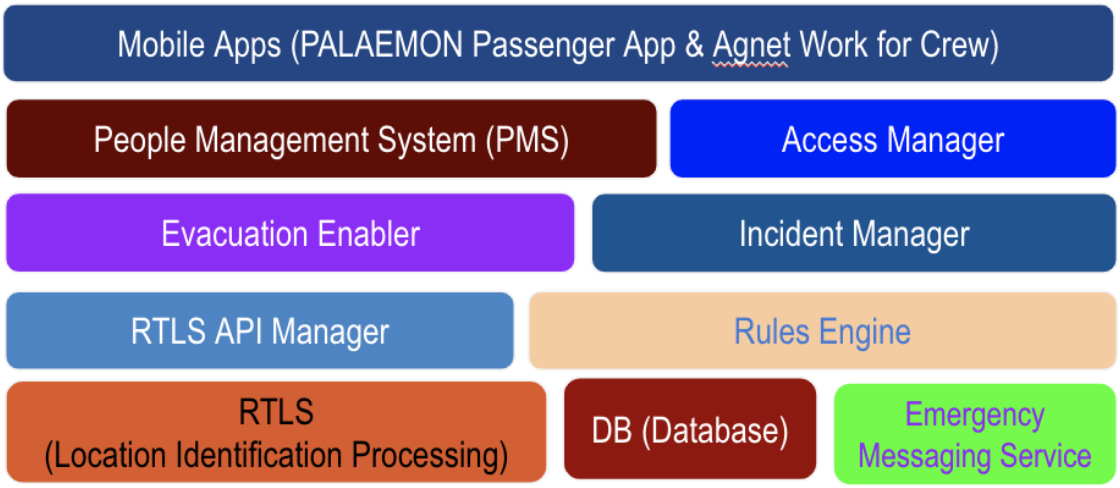

Figure 10: PaMEAS-A architecture overview

Note: PaMEAS-A integrates with the underlying network layers, PaMEAS-W and PaMEAS-Cell. via the following network interface components: RTLS and Emergency Messaging Service (Mumble/Tactilon Servers).

Table 4: PaMEAS-A Architecture Updates

Technical Architecture Component	Status
PaMEAS-A	Instantiation of original high level architecture of D5.9 to a set of concrete microservices with specific functionalities, integrations and flows.

The architecture of PaMEAS-A is presented in Figure 10. Table 5 presents a short description of the individual microservices consisting PaMEAS-A. A detailed description of each module is provided in D5.14 PaMEAS Software Suite: Deployment (V2) [4].

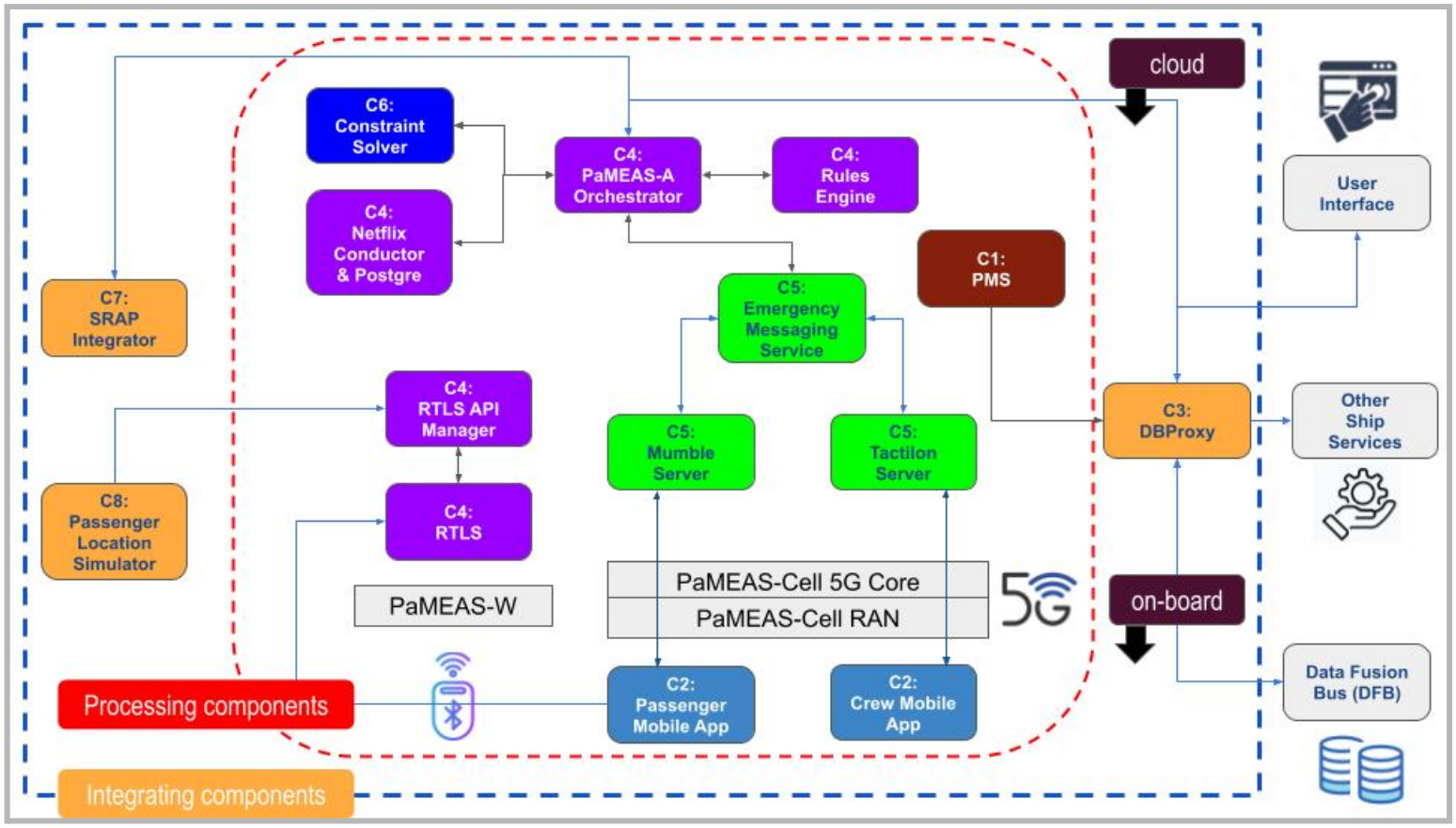

Figure 11: PaMEAS architecture and components in detail

Table 5: PaMEAS architecture: List of components

no.	High Level Component	MicroServices - Implementing High Level Component	Description
Processing Components			
C1	People Management System (PMS)		
		Embarkation Registration Service	Passenger (and Crew) Registration Service
		PaMEAS VC System: - PaMEAS VC (Verifiable Credentials) Issuer - PaMEAS VC Verifier	Backend service of the PMS generating and managing the lifecycle of the PALAEMON Service card
		Trusted Registry	Revocation Registry for PALAEMON Service Cards
C2	PALAEMON Mobile Apps		
		PALAEMON Passenger App	Mobile app for the passengers supporting real time location
		PALAEMON Crew App (Agnet Work)	Mobile app for crew members enabling Mission Critical Push to Talk (MCPTT) communications
C4	PaMEAS Evacuation Enabler		
		Real time Location Service (RTLS)	Over cloud or “on premises”
		RTLS API Manager	Location monitoring and pushing to persistence
		RTLS-Load Balancer	Load balancing (nginx)
		Netflix Conductor & Postgre	Microservices Orchestration Engine
		PaMEAS-A Orchestrator	Orchestrator implementing PaMEAS-A flows using Netflix Conductor

		Rules Engine	Rules Engine to support message generation and passenger routing selection
C5	PALAEMON Emergency Messaging Service		
		Core Messaging Service Module **Mumble Server** **Tactilon Agnet Work**	Messaging functionality over Websocket and external services (Airbus Tactilon Agnet)
C6	PaMEAS Incident Manager		
		Constraint Solver (OptaPlanner)	AI constraint solver to assist with Passenger issues
		Pathfinder	Utility service that helps calculate distances on board the decks
		Rules Engine (Drools, API over Drools)	AI Rules Engine to support message generation and passenger routing selection
Peripheral Components			
C3	PaMEAS Access Manager		
		PaMEAS OAuth 2.0 server Keycloak	OAuth 2.0 Authorization & User Identification
		PaMEAS DBProxy Service	Persistence API
		PaMEAS DBProxy Load Balancer	Load balancing (nginx)
C7	PaMEAS-SRAP Integrator		
		PaMEAS DBProxy Service	
		Orchestrator (Conductor)	
C8	PaMEAS Passenger Location Simulator		

		PaMEAS Passenger Location Simulator	Simulates movements of passengers

5 Updates to PaMEAS privacy vision

Location-Based Services (LBS) are applications and services that use the user's current location to provide various functionalities. Location data privacy is a significant issue when it comes to LBSs. It refers to the individual's right not to be subjected to unauthorised collection, aggregation, processing, and distribution of their location data[3]. PaMEAS architecture has been developed to comply with location data privacy principles, including lawful processing of personal location data, data protection by design and default, data minimization, and secure data processing activities. The architecture ensures that, outside of emergency situations where every privacy constraint is lifted to ensure the prevention of loss of life, access to the passengers location data is always under the sole control of the passengers.

Table 6. PaMEAS Privacy Architecture updated

Technical Architecture Component	Status
PaMEAS Access Manager	Definition of the required access control policies and encryption standards to ensure privacy of passenger location data
People Management System (PMS)	Definition of the mechanisms for the generation and use of the PALAEMON Access Card. A W3C Verifiable Credential[4] (VC) that can be used by the passengers to control access to personal location data outside of emergency situations

In details, access to passenger location data is enabled only under the following conditions:

1. The passenger explicitly gives consent to the access of their location data to specific services
2. An emergency is taking place (in which case passenger safety takes precedence over location data privacy considerations)

The technical components ensuring this functionality are:

- the PaMEAS Access Manager
- the People Management System (PMS)

Specifically, the passengers location data are always stored encrypted using the PaMEAS Access Manager component (specifically the PaMEAS DBProxy Service). Other PaMEAS (and PALAEMON in general) services can query for this data only if they are authorised to

[3] A W3C Verifiable credential is a digital credential that can be verified by a third party using cryptography. It can represent information found in physical credentials, such as a passport in a secure tamper evident manner that enables the instant verification of ownership. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC119398/jrc119398_jrc119398_guidelines_for_public_administrations_on_location_privacy_v2.pdf

[4]

do so (authorization is ensured via the PaMPaMEAS Access Manager; OAuth 2.0 server Keycloak service).

By default only the following PALAEMON services are authorised to query for location data (and only in case of an active emergency incident):

- C4: PaMEAS Evacuation Enabler; see Section 4.
- C6: PaMEAS Incident Manager; see Section 4
- SRAP: Smart Risk Assessment Platform; service calculating risks about the health conditions of the passengers and the overall process of the evacuation.
- PALAEMON Incident Management Module (PIMM): Implements the Bridge Dashboard user interface of PALAEMON. Specifically, it provides visualisation UIs for the location of the passengers and crew members. Furthermore, it provides visualisation UIs about the progression of the mustering process (generated by PaMEAS).

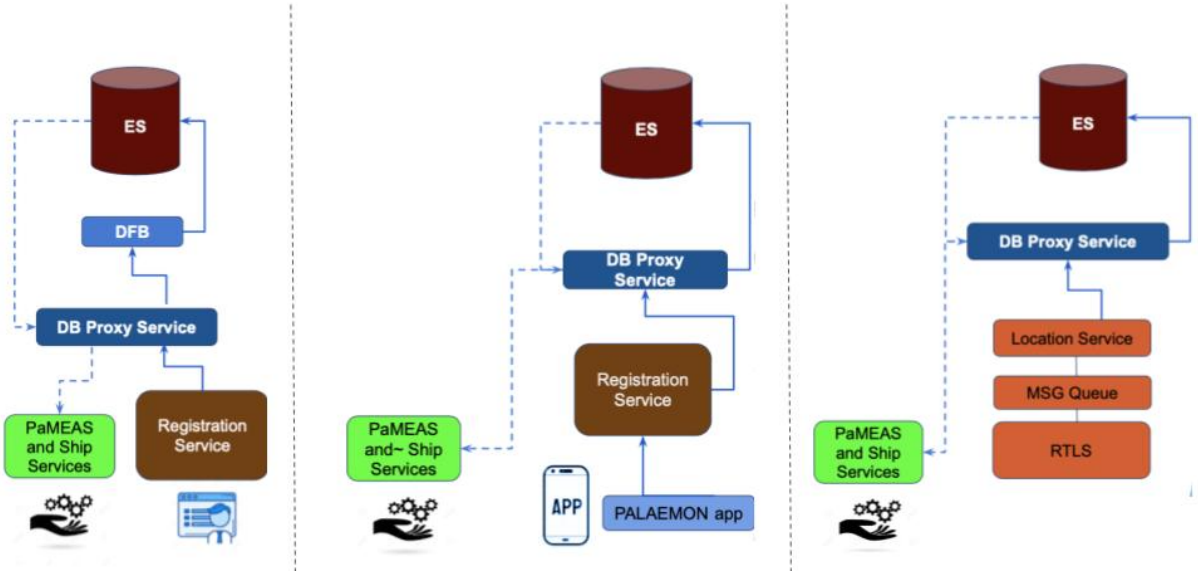

Figure 12: Implementations of PaMEAS Access Control mechanism

Further details about the implementation of this access control policy can found in the following reference documents:

1. https://docs.google.com/presentation/d/1MwXEf7tc2a9sANBsxOAwitxY7Gbb4oov/edit?usp=sharing&ouid=101096721707031783382&rtpof=true&sd=true
2. https://docs.google.com/presentation/d/16W8H_h-qz2HTbRwcXpGJ9RnrYqZxCAZ8/edit#slide=id.g109536bd6dd_2_1004

When an emergency incident is not active, passengers are enabled to authorise and revoke access to their location data via the PALAEMON Service Card, using the PaMEAS PMS component. The PALAEMON Service Card is a W3C compliant VC issued to the passengers of PALAEMON via the dedicated VC issuer service (part of the PMS component), as part of

the passengers registration process. This card can be consumed via the PaMEAS VC Verifier service, also part of the PMS component. Usage of this card ensures the strong authentication and identification of the user (passenger or crew member) in any enabled service.

PaMEAS uses the PALAEMON Service Card as:

- Its primary mechanism
- As an authorization mechanism allowing passengers to express their consent for any PaMEAS-enabled ship service (even outside the context of PALAEMON) to be granted access to their location data.

Essentially, the PALAEMON Service Card ensures the sole control of the user as to what service can gain access to their location data, enabling the user to customise the access control policy (with respect to their own personal location data).

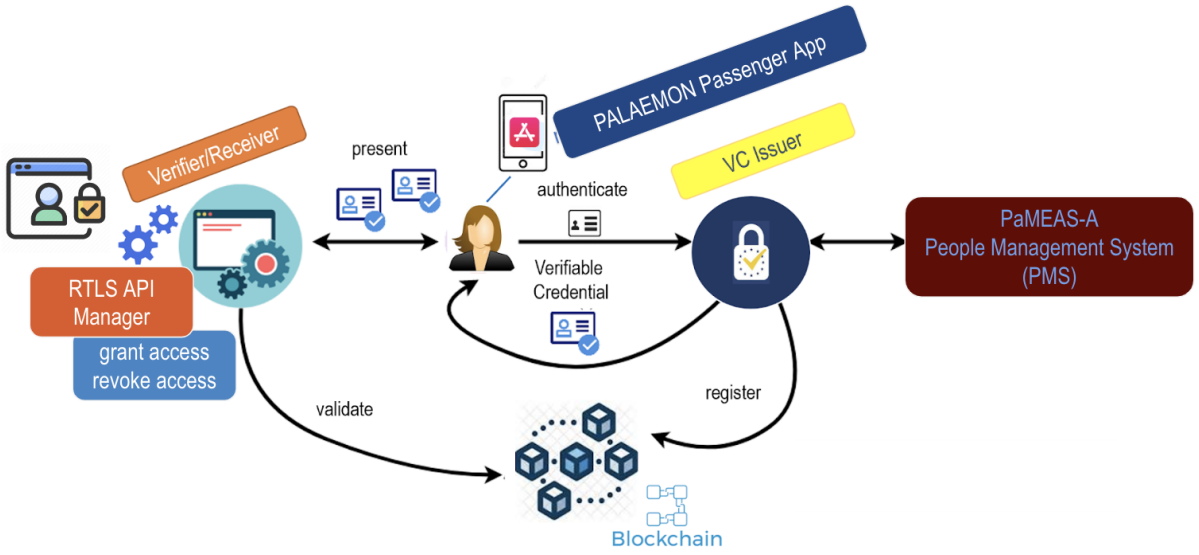

Figure 12: Passengers grant and revoke access to their location data by using their Service Card (access to passenger location data is automatically enabled in the case of an emergency)

Further details about the implementation of this functionality can be found in the following reference document:

1. https://docs.google.com/document/d/1Y0Dq2gu1K9QH_rNi8AgLxfBZ96dPmtskyWvEZB4cRHo/edit

6 References

[1]. PALAEMON D5.9 “PaMEAS design principles and Technical Architecture (V1)”
[2]. PALAEMON D2.4 “First version of PALAEMON Use Cases Definition & Operational Requirements”
[3]. PALAEMON D2.6 “PALAEMON Architecture (V1)”
[4]. PALAEMON D5.14 “PaMEAS Software Suite: Deployment (V2)”