SafePASS Core Platform

Introduction

Current evacuation procedures involve two phases: mustering, which involves moving people away from a designated area to a safer area or to the muster stations and abandoning the ship (embarkation and launching lifeboats). Evacuating a large and complex environment such as a large passenger ship is a safety- critical and strictly time-bound task, which typically involves thousands of people moving within parts of the ship, assisted by a significant number of crew personnel, and a complex decision-making process based on the evolving situation on-board and the information available to the decision makers. Timely mustering and abandonment require fast and accurate evaluation of ship's conditions as well as estimation of remaining time.

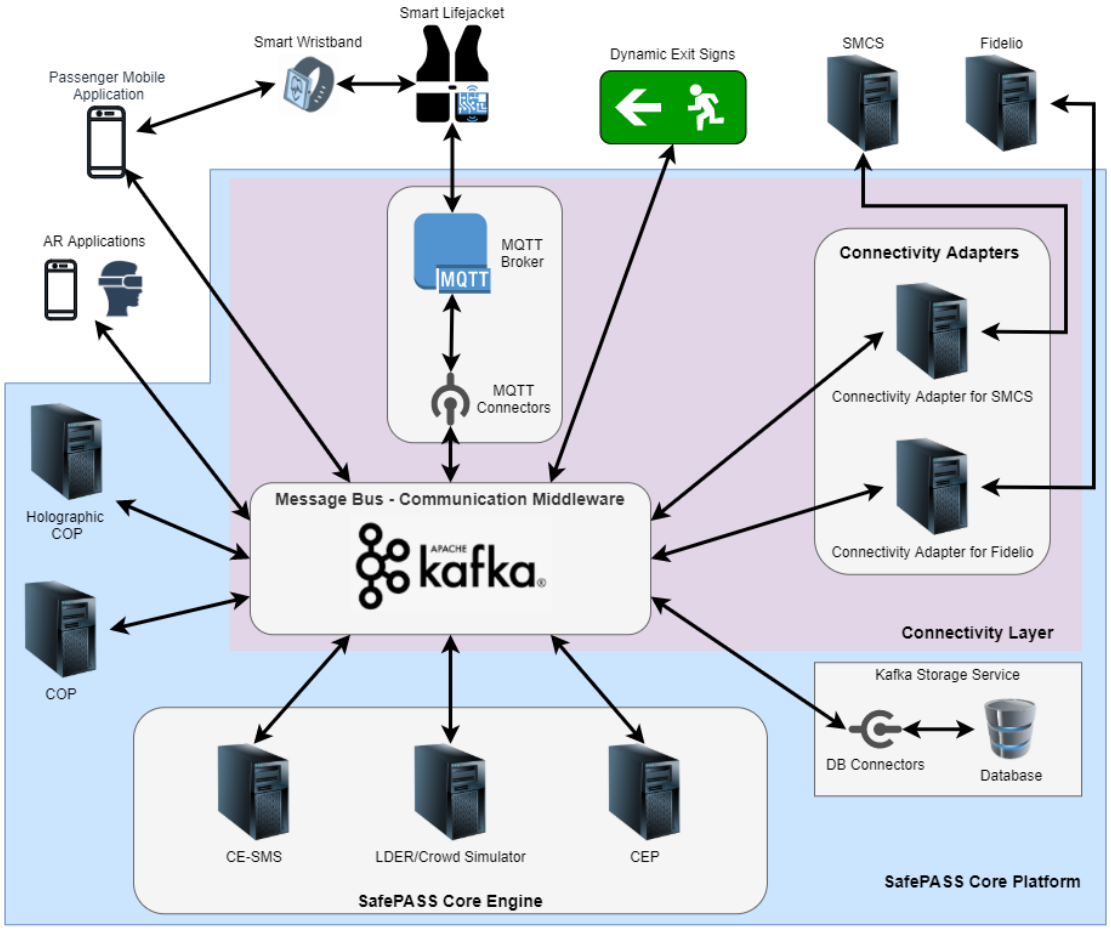
However, current procedures and plans insufficiently address the actual challenges of an evacuation, particularly in the presence of flooding, fire hazards and extreme environments. Similarly, they fail to adequately account for human behaviour during stressful situations and lack of resilience.

Passengers are instructed to return to their cabins to collect lifejackets before heading for a pre-defined assembly (or muster) station. They must then exit the ship by getting to lifeboats, life raft and possibly evacuation slides, for which they have no training and in some cases are very reluctant due to arrangement of equipment (e.g. use of chute), physical limitations or even personal ones (e.g. elderly or claustrophobic people). The ship is floating on waves and this may result in significant motions and accelerations. Furthermore, in case of flooding, it may list or even capsize rapidly. The assumption that all these people will be able to comprehend and follow instructions or even that the crew will be able to communicate verbally during a crisis is very optimistic.

SafePASS aims to radically redefine the evacuation processes, evacuation systems/equipment and international regulations for passenger ships in all environments, hazards and weather conditions, independently of the demographic factor, by developing an integrated system that will collectively monitor, process and inform during emergencies both crew and passengers of the optimal evacuation routes, coupled with advanced, intuitive and easy to use LSA, resulting as such to a significant reduction of the total time required for ship evacuation and increased safety.

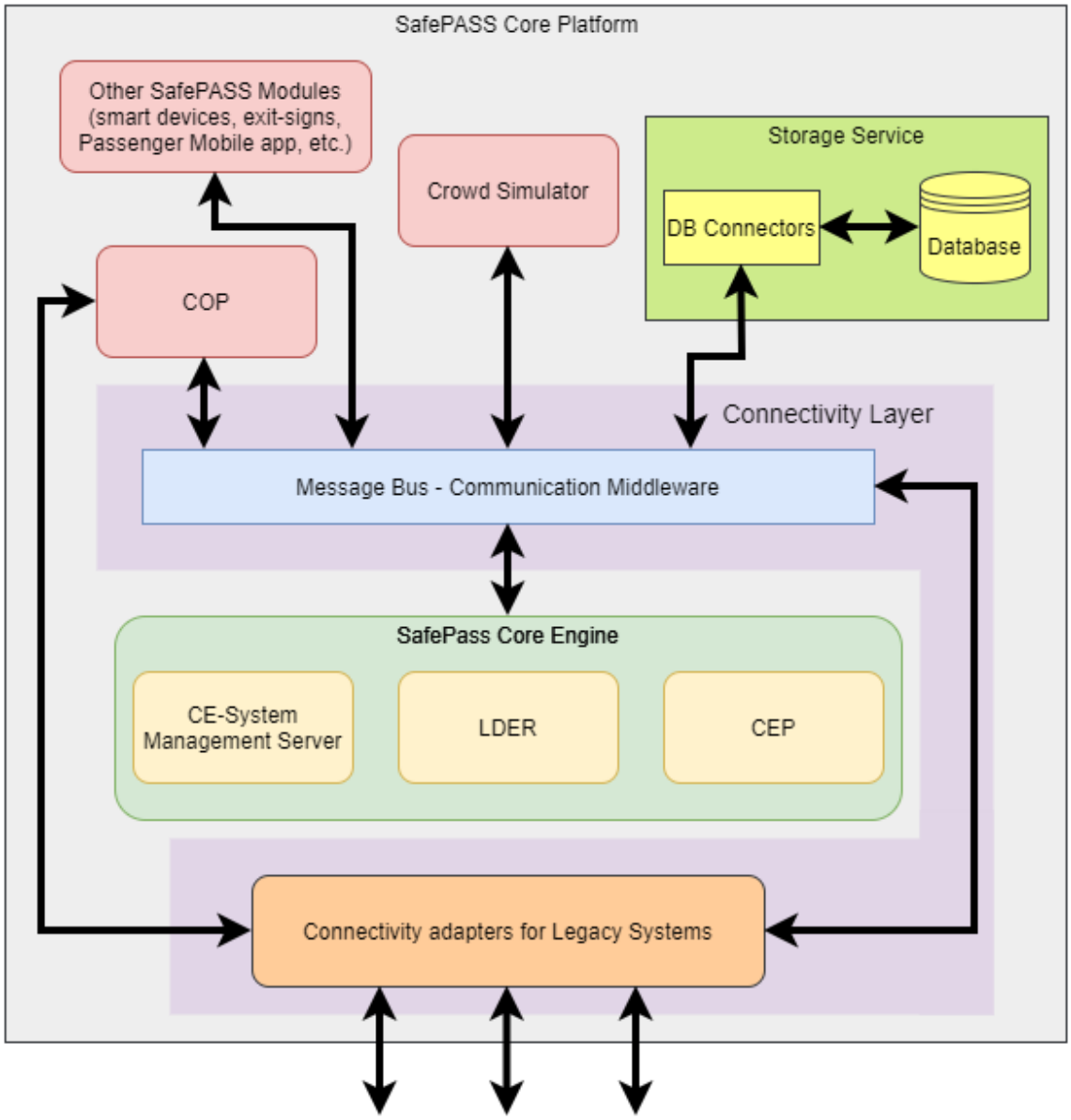
Core Platform

The Core Platform is the fundamental, integrated system in the SafePASS solution. It consists of several simple and multilayered modules that perform different functionalities, either dependent or independent in terms of data exchange. The Core Platform includes all the necessary services that handle, record and monitor the flow of information among different SafePASS modules. The COP, the Holographic COP and the Connectivity Layer, along with the integrated Kafka Storage Service and the Core Engine are the modules that make up the SafePASS Core Platform. Some key external systems, that are connected directly and exchange information with the SafePASS Core Platform, include the Dynamic Exit Signs, the Passenger Mobile Application, the AR Applications and the Smart Lifejacket. Additionally, there are the two external legacy systems of the cruise ship, the SMCS and the CSMS (Fidelio) that communicate exclusively with the connectivity adapter services of the Connectivity Layer of SafePASS Core Platform. The overall architecture of the SafePASS solution is presented below.


Smart Lifejacket
Smart Wristband
Passenger Mobile Application
Dynamic Exit Signs
SMCS
Fidelio
AR Applications
MQTT Broker
MQTT Connectors
Connectivity Adapters
Connectivity Adapter for SMCS
Connectivity Adapter for Fidelio
Holographic COP
COP
Message Bus - Communication Middleware
kafka
Connectivity Layer
Kafka Storage Service
DB Connectors
Database
CE-SMS
LDER/Crowd Simulator
CEP
SafePASS Core Engine
SafePASS Core Platform

Core Engine

The Core engine is responsible for the generation of evacuation routes, the handling of the Dynamic Exit signs, producing warnings and alerts based on information received from sensors and acts as a centralized management and configuration point for the entire SafePASS platform, whose goal is to act as a safety management and control platform that provides holistic situation awareness and real-time adaptive evacuation strategies on large cruise ships



The Core Engine is comprised of three subsystems. The System Management Server (CE-SMS), the Location-based Dynamic Evacuation Route (LDER) and the Complex Event Processor (CEP). It is also important to note the Communication Layer and the Dynamic Exit signs.

CE-SMS

Functionalities of the CE-SMS aims, which is built upon a Microservices Architecture (to support different functionalities, while preserving loose coupling between the systems) include the

monitoring of SafePASS subsystems, the discovery, registration and management of SafePASS entities, geo-location-based association of the various smart devices and actuators within the LDER and the maintenance of a software registry which the CE-SMS depends on.

The above functionalities are supported by the following services:

- **Discovery service:** Implemented to act as a registry for the software.
- **Gateway Service:** Used to handle the incoming requests between the CE-SMS services and also external services.
- **Configuration Server:** Provides centralized configuration for every service of the CE-SMS.
- **Health Registry Service:** Monitors and records the status in terms of connectivity and functionality of all subsystems and sensing elements and exit-signs connected to SafePASS.
- **Device Registry Service:** Realizes the discovery and registration of all sensors in the system and the record of their published values to middleware.
- **Exit-Sign Management Service:** Responsible for the geolocation association and control of exit-signs based on LDER. An algorithm is designed and implemented in order to remotely control the exit signs presented directions based on the published active evacuation route by the LDER module, with the ultimate goal of providing evacuation directions in an accurate and timely manner.

LDER

The (Location-Based Dynamic Evacuation Route Component) LDER contains the algorithms required to forecast passenger movement and determine the optimal evacuation routes. Within the LDER, the presentation layer visualizes the crowd simulation network of the ship and the communication layer which receives input and instructs what simulations to be run.

The LDER (Location Based Dynamic Evacuation Route Launch time) is primarily a calculation of dynamic routes allocated to passengers allowing them to follow the best, safest and fastest routes.

The LDER is part of the SafePASS core system, taking data from various sources around the ship such as indoor localisation, counting and incidents and generating outputs such as crowd congestion and routes that can be displayed on the common operational picture (COP) on the bridge and communicated to passengers via active exit signs, app or life saving appliances.

The LDER component is made up of many different system parts that can be separated into 3 main parts:

- **LDER route calculation,** which calculates the optimum routes
- **SafePASS crowd Model Designer (SMD),** which is a visual software tool used to input the ship layouts, routes and simulation parameters to be used in the route calculation
- **Fire and flood propagation simulations**, which model the spread of disaster in the ship

Different strategies are simulated to estimate the best evacuation time. The intention is to take into consideration the needs of a passenger, for example accessible routes, keeping families together and using demographic information to model crowd movement and behaviour. An example of this is for elderly cruise ship passengers who may move more slowly and not react as quickly to an emergency situation.

Fire and flood simulation data will be used to prevent routing passengers to a dangerous area. If passengers are moving in a compromised area the model will reflect a change in the crowd flow.

CEP

The Complex Event Processor (CEP) is responsible for the real time detection of hazardous events, data storage and providing warnings. Functionalities include rule extraction, data formation of warnings and alerts, date storage queries, data storage and the CEP communication. It is based on event processing methods for tracking and analyzing incoming streams of data from sensors, legacy systems, and other SafePASS subsystems, in order to formulate events about the current status of the ship and derive a conclusion from them (e.g. a fire alert).

These different processing stages are as follows:

- **Transformation:** An explicit translation step, the data format is changed to another format appropriate for further processing. Note that during this step no new information is added to the information stream.

- **Filtering:** Information that is not required for further processing is logically removed from the stream i.e. only relevant information is passed to the next stage.

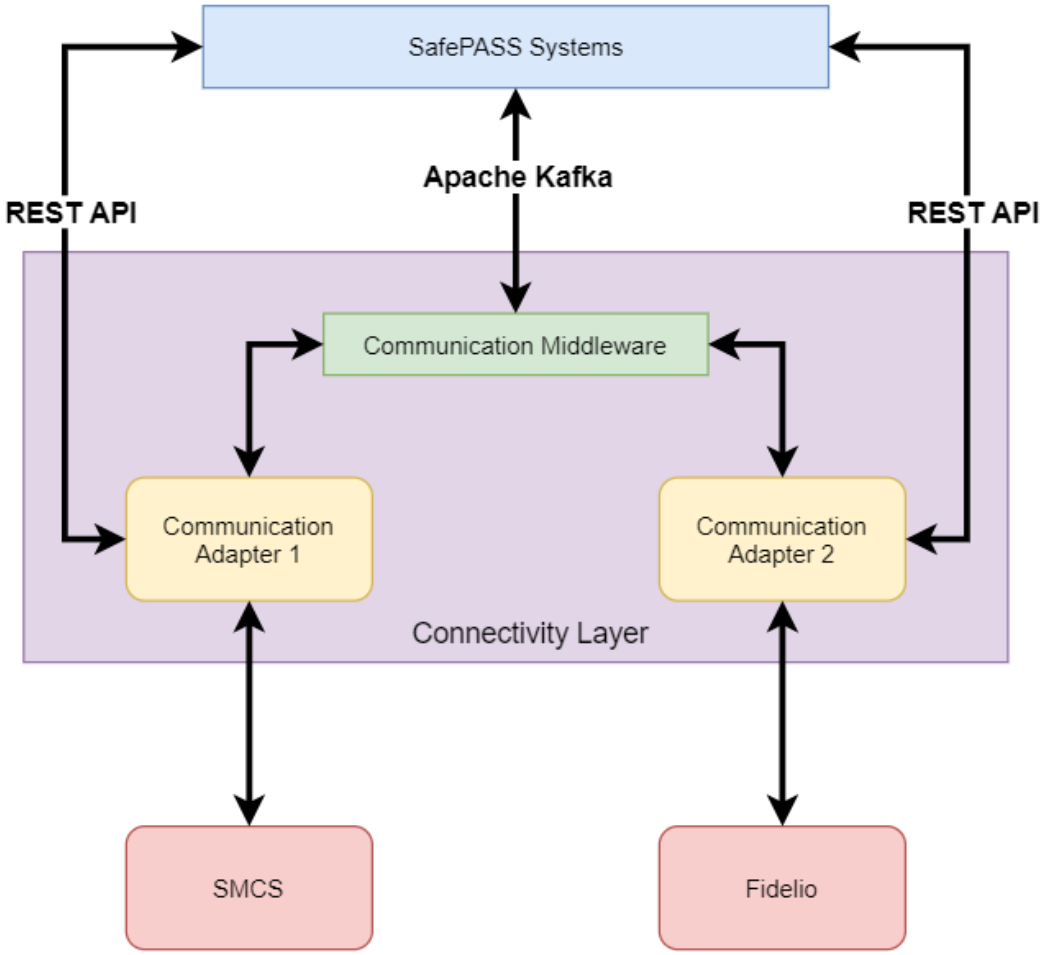
- **Content Enrichment:** During this stage the event object is enriched with additional structural information by accessing relevant streams of information.

- **Granularity Shift:** At this stage, many events are aggregated to a new, composite event. The aggregations that take place here uses simple numerical operations (e.g. averages or sums of specific fields, aggregations based on date-time etc.) for correlating events of the same type.

- **Semantic Shift:** The final step of event synthesis, the composite event that produced from the final step is associated with pre-defined correlation sets. These correlation sets are based on simple or more complex event patterns, the rules for alerts or warnings, with respect to the knowledge of the domain (e.g. cruise safety). Semantic patterns describe complex dependencies between events taking temporal constraints into account (e.g. fire incident in a ship area).

Communication Layer

The Communication Layer is responsible for the exchange of the messages between different SafePASS components. It handles all the traffic and forwards the messages to the appropriate services. Every service is connected to the message bus and uses listeners to consume the corresponding data needed to work properly. It is comprised of a Communication Middleware and Connectivity adapters, and built upon Apache Kafka (a robust publish-subscribe messaging system), facilitates the exchange of messages between the Core Engine and different SafePASS components. The Connectivity Adapters extract important data from the cruise ship legacy systems, such as safety information related to flooding and fire, and administrative data such as passenger information. The below diagram illustrates the architecture of the communication layer.



COP

An overview of the different COP components and their functionalities

The COP and it's components provide a holistic and multidimensional view of the ship and of the ongoing situation. It dramatically enhances situational awareness and monitoring within a dense and complex indoor environment such as a cruise ship's. It also supports real-time, adaptive evacuation strategies and improves the safety and security of passengers and crew members alike. These components can be deployed on the bridge, to orchestrate operations, as well as anywhere in the ship to support first responders. It comprises the following systems:

COP Server

The COP Server, based on a MongoDB database, ensures the consistency and the coherence of data displayed by the COP clients. It also manages user and group access, and the timestamping of all data offers the opportunity to replay a session for debriefing.

2D/3D COP

The 2D/3D COP is an ergonomic and intuitive application adapted to workstations and touchscreen tables for operational command to handle crisis situations from the Safety Centre. This application

provides users with a complete and global overview of the situation to facilitate discussion and decision-making. This application allows to navigate on the ship and visualise legacy-system information, in real time, including weather conditions, CCTV streams, sensors states and values, alerts, incidents and, in case of an evacuation, passengers' location, densities per room, as well as the complete evacuation routes. Finally, this tool makes it possible to detect new incidents and raise an alert at any time, to communicate with field safety crew and to organise and coordinate rescue and ship evacuation.

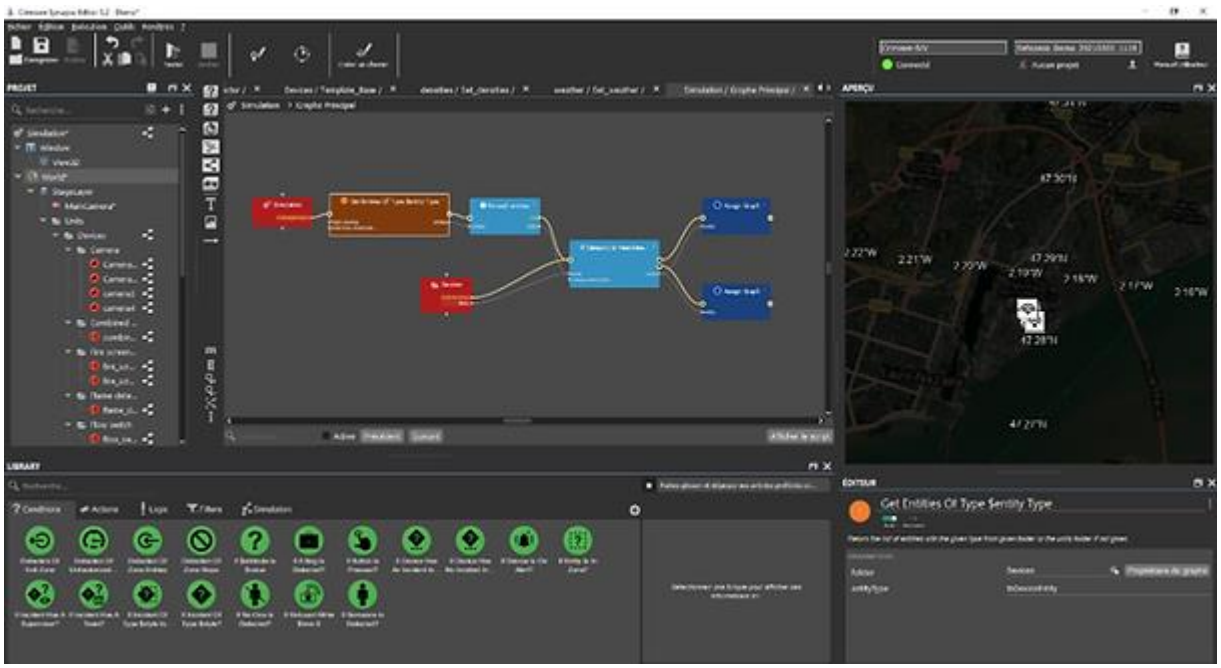
Holographic COP

the Holographic COP is an augmented-reality smart-glasses application for field safety crew. This novel and innovative equipment favours user mobility and the exchange of information within the command post. This hands-free application offers the ability to visualise and manipulate the ship, to focus on individual areas and to provide information such as user location, sensor states and values, alerts, evacuation routes or the location of passengers missing at the muster stations. Finally, this application assists first responders with their assigned tasks, allowing them to communicate with the Safety Center, to receive commands and report incidents and pictures.

Scenario Editor

The COP Scenario Editor, based on a CS Group product, is an authoring tool that can be used to automate behaviors and create scenarios. Such behaviors can be played on the Scenario Editor itself or published on the COP Server to be running in the background. In the SafePASS project, this visual programming application is used to create and manage 2 tasks:

- the creation of complex and realistic scenarios for training or validation purposes
- a network communication plugin ensuring the transfer of information between the COP Server and the Holographic application.



Smart devices

As part of the overall SafePASS solution, several key systems that work in conjecture with the Core Platform allow for indoor localization and personalized services for both crew members and passengers.

AR Crew Application
The Augmented Reality Crew Rescue Assistant Application aids crew members in passenger location when they are in need in need of assistance. When activated, the application identifies the user (crew member), receives the passenger's data along with a route and then navigates the user to the passenger's location. To accomplish this, the application will communicate with Bluetooth beacons (indoor localization module installed) in order to identify current position and location and with Core engine to receive passenger related data along with the route to passenger's location.

Passenger Mobile Application
The passenger mobile app will provide visualization of the passenger's location, as well as graphical navigation instructions based on the provided (by the LDER component) evacuation route. This will be the same evacuation route provided from Core Engine to other SafePASS components, such as the Smart Lifejacket, so there will be no contradiction between them even in the case where they will run simultaneously. The passenger mobile app will also offer additional information, e.g. data updates and feedback from the Core Engine. It will provide direct communication among family members through predefined text messages, as well as an easy way for the passenger to request assistance from the ship crew.

Smart Lifejacket
The Smart Lifejacket provides situational awareness and on-demand navigation for the passengers. To achieve this, it communicates with multiple components of the SafePASS System, sending a personal evacuation route to each passenger based on their respective location, which is relayed through haptic navigation actuators. The smart lifejacket features may be utilized at different phases of the emergency and depending on where the lifejacket is available for the passenger (stowed at the cabin or at the muster station).

Smart wristband
The Smart wristband will be used for physiological monitoring of passengers in case of an emergency. The smart wristband will read the passengers' biometrics and make them available to the SafePASS system. The smart wristband will be handed out to the passengers prior or during the embarkation. It will contain a unique identifier associated with the specific passenger. Under emergency conditions, the smart wristband is used for associating the specific passenger with the lifejacket and for monitoring passenger's biometrics, while in normal conditions this functionality is not available.

Dynamic Exit signs

The Dynamic Exit Signs are responsible for displaying live evacuation directions. They display the safest path according to the dynamic evacuation route provided by the Core Engine during an emergency. Each Exit Sign will communicate with the Core Engine through the messaging middleware. After being enabled, the signs display the evacuation route under normal conditions.

When the evacuation directions change, the signs display the new directions. Additionally, they publish health status updates to the Core Engine.

Technology demonstration in a relevant environment

The SafePASS solution was demonstrated in a pilot test on the 23rd of February at the Chantiers de L'atlantique shipyard in St Nazaire, in which a variety of scenarios were played through in order to emulate possible incidents that could occur on a cruise ship. During the pilot, different groups made up of volunteers from the shipyard used the different technologies to play out the scenarios. The roles of the different technologies are listed below:

The Core Engine: The Core Engine acted as the operational backed of the SafePASS system during the pilot. It was responsible for managing the communication, connectivity and state of all the different systems (facilitated through KAFKA and REST API), as well receiving and sending data from the on-board legacy systems (simulated data was used to represent necessary passenger data and sensor data, such as fire and smoke) and sending alerts to the COP based off sensor data.

The Location-Based Dynamic Evacuation Routes (LDER): The LDER calculated the passenger densities on board as well as the most appropriate evacuation routes based on data received from the Core Engine.

The COP and holographic COP: The COP visualized different incidents produced by the Core Engine and Holographic COP and live footage from the CCTV cameras on board for a better management of the evacuation scenario. It also visualized the ever-changing evacuation routes and allowed the COP operator to block certain evacuation paths, set off appropriate alarms based on the incident and assign tasks to crew members. The holographic COP was used by a crew member to report incidents in different areas of the pilot area.

The Dynamic Exit Signs: The Dynamic Exit Signs displayed new evacuation routes calculated by the LDER based on the respective scenarios, leading passengers to their muster stations or evacuation points.

The Passenger Mobile app: The Passenger Mobile app displayed evacuation routes calculated by the LDER based on the passenger location (using BLE beacons), but also allowed passengers to request assistance when necessary.

The AR crew app: The AR crew app allowed crew members to respond to incidents, such as localizing and finding passengers who requested assistance or who were in distress (based off their biometric data).

The smart wristbands: The smart wristband was used to measure biometric data of passengers and to activate the smart lifejackets.

The smart lifejackets: allowed for passenger localization (using UWB anchors) and haptic navigation through the LDER calculated evacuation routes.

Working together, the different technologies that comprise the SafPASS solution provided a holistic evacuation management system during the test. For example, in the final scenario, the COP operator

assigning a crew member wearing the Holographic COP to assess damage to certain evacuation routes. The crew member assessed the damage and reported back to the COP operator, after which the specific route is blocked by the operator and the general alarm sounds off. Two passenger groups from different locations used the exit signs and mobile app to go to an unobstructed muster station where they put on their lifejackets. Fire and smoke were then detected, so the passengers were guided to a different muster station. There was also a passenger which requested for assistance using the mobile app, who was assisted by a crew member using the AR crew app.

Conclusion

Modern ship evacuation faces many complications when it comes to evacuation, including the dynamic nature of emergency situation, human behaviours and lack of situational awareness to all involved. The SafePASS solution is an integrated system that will collectively monitor, process and inform during emergencies both crew and passengers of the optimal evacuation routes, cutting own on time and complexities when it comes to ship evacuation.

The Core Platform is a central system in the SafePASS solution and consists of the Core Engine, COP, Crowd Simulator, Storage Service and Connectivity Layer. Additionally, it interacts with external systems such as the Dynamic Exit Signs, the Passenger Mobile Application, the AR Applications and the Smart Lifejacket.