Multi-Partner Project: ENABLING DIGITAL TECHNOLOGIES FOR HOLISTIC HEALTH-LIFESTYLE MOTIVATIONAL AND ASSISTED SUPERVISION SUPPORTED BY ARTIFICIAL INTELLIGENCE NETWORK (H2TRAIN)

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***Abstract*— H2TRAIN aligns with the ECS Strategic Research and Innovation Agenda 2023 (ECS-SRIA), addressing key challenges in integrating digital technologies for health-focused lifestyles through AI-enhanced networks. This project pioneers the use of graphene to develop autonomous biosensors within CMOS technology, supporting advancements in AI-powered health services and IoT applications. Beyond digital integration, H2TRAIN innovates in energy detection, collection, and storage, essential for embedding health and sports functions in IoT wearables through smart textile and system integration. The solutions will be rigorously tested and validated with insights from medical, sports, social sciences, and end-user feedback. Focused on remote assisted living, amateur sports training, and post-operative monitoring, H2TRAIN aims to drive innovation in the smart healthcare sector, where investment in semiconductor nanofabrication is limited by the small scale of medical applications.**

Keywords—Internet of Things (IoT), artificial intelligence (AI), edge computing, embedded intelligence, more-than-Moore devices, heterogeneous integration of functionality, biosensing devices, energy harvesting, 1D and 2D-materials.

I. INTRODUCTION

Biosensors for e-health and smart tracking of sports and fitness are rapidly growing in both the consumer and professional markets. Despite the impressive advancements in current technologies, several transformative improvements remain, particularly in four key areas: (i) sensing new bio-signals and tracking novel activity patterns; (ii) extending battery life and enhancing energy management for continuous use; (iii) ensuring secure, reliable, and efficient data analysis through AI algorithms; and (iv) enabling seamless connectivity with the Internet of Things (IoT).

H2TRAIN aims to push the boundaries of these technologies by leveraging the unique properties and synergistic potential of one-dimensional (1D) and two-dimensional (2D) materials (1DM and 2DM). This approach will enable more sensitive, efficient, and miniaturized biosensing capabilities within the established CMOS technology framework. The project will contribute to the growth of AI-assisted e-health services and foster the development of IoT applications in health, well-being, and the digital society. Furthermore, H2TRAIN not only advances digital technology but also develops new 1DM and 2DM-based devices for sensing, energy harvesting, and supercapacitor storage, facilitating the integration of sports and health activities into IoT-enabled wearable technologies.

A. Emergent Technologies combined with mature CMOS

H2TRAIN integrates mature CMOS technology products with embedded intelligence for health and sports sensing, enabling a variety of advanced technology demonstrators (TDs). These include sophisticated sensors like tattoo-based sweat monitors for glycemic levels, pH, C-reactive protein, cortisol, lactate, alongside ECG, EMG, and SpO2 signals. Inertial measurement units (IMUs) and energy harvesting systems, based on thermoelectric (TE) and radio frequency (RF) technology, enhance health and sports trackers. H2TRAIN's textile-integrated TDs are applicable in Remote Assisted Living (RAL), Intelligent Adaptive Sport Coaching (IASC), and Remote Post-Surgery & Rehab Monitoring (RPS&RM).

Advancements in 2D materials for e-textiles emphasize flexibility, miniaturization, and integration into wearable technology, offering solutions like fibers and textiles that are lightweight, breathable, and adaptable to traditional clothing. Artificial Intelligence and edge-based machine learning further enhance these wearable microsystems. Smartphones and smartwatches now provide widespread access to fitness, sports guidance, and e-health services, with AI-driven cloud services supporting personalized training programs across various sports. Additionally, advancements in movement monitoring and 3D image processing are enabling remote training in technical sports, such as swimming, through online platforms.

2DM are quite suitable for being fabricated on flexible substrates as textile components, i.e., e-textiles with electronics properties are becoming familiar, too. However, there are some drawbacks that still need to be addressed as follows. 1) Technologies based on electrical cables for wiring, networking, connecting, and contacting mostly suffer from a mismatch between rigid electronics and flexible textiles, which severely disturbs wearing comfort. 2) The precision and

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the reliability of parameter estimation, in dynamic conditions, is often hindered by several factors, including individual idiosyncrasies as well as poor data links. Errors might be easily more than 10%. 3) Though security of standard communication protocols for personal area networks has grown over the years, reinforcement is still advisable in areas such as the protection of personal data and compliance with General Data Protection Regulation (GDPR). 4) Finally, while the smart wearables market is huge and steadily growing at a 2-digit rate, Europe is not in the leadership, but this gap can be closed by leveraging on the European leadership on semiconductor nanofabrication of smart sensors addressing innovation and market perspective along the entire supply chain of these devices rather than only in one step of it.

B. *Embedded Intelligence and Edge-Cloud Continuum*

H2TRAIN aims to harness wearable technologies to tackle the technological challenges associated with advancing IoT, AI, and edge computing solutions. Meeting these objectives demands innovations across various fields, including the continued progress of Moore's law, advancements in functional building blocks, integrated circuits, electronic performance, more-than-Moore devices, and the heterogeneous integration of functionalities. This multi-faceted approach positions H2TRAIN to deliver significant technology-driven benefits that address society's evolving digital needs.

A key innovation within H2TRAIN is the integration of embedded intelligence across a computing continuum—spanning edge, fog, and cloud computing— alongside rigorous personal data security measures. Together with the application layer, this robust framework supports the development of digital twins, big data analytics, and advanced data processing capabilities.

In the H2TRAIN project, algorithms will be refined using data collected in vivo with support from experts in exercise and sports medicine. H2TRAIN's smart body sensors monitor a range of vital parameters, including heartbeat, muscular strain, respiration, energy expenditure, blood pressure, oxygenation, position, velocity, force, acceleration, and other real-time biomechanical data for the body and limbs. Wearable devices, composed of sensors for electrophysiological data, data communication units, and data acquisition/analysis modules, meet these application needs effectively. These devices, already popular for tracking heart rate, calories burned, or daily steps, are gaining further traction as people increasingly prioritize a healthy lifestyle.

C. *Technology Validation by Use Cases*

Finally, H2TRAIN will design, test, and validate its solutions from both medical and sports science perspectives, with substantial input from social sciences, humanities, end-user groups, and related stakeholders throughout the development cycle. By addressing three core use cases—remote assisted living, intelligent adaptive sport coaching, and remote post-surgery and rehabilitation monitoring—H2TRAIN aims to unlock the potential of digital technologies across both recreational sports and smart healthcare, helping bridge the investment gap in semiconductor nanofabrication for typically low-volume medical applications.

In H2TRAIN, with the help of renowned partners in the field of exercise and sports medicine, the algorithms will be improved based on in vivo collected data. The enabling technologies are smart body sensors which monitor vital parameters such as heartbeat, muscular strain, respiration, but also energy expenditure, blood pressure, oxygenation, position, velocity, force, accelerations and in general biomechanical parameters for the full body and/or the single limbs in real-time. Wearable devices are a good solution to the addressed application needs.

In principle, wearables mainly consist of three groups of units, namely, one or more sensors that measure electrophysiological signals, a data communication unit, and a data acquisition/analysis unit. They are primarily employed for logging parameters like heart rate, burned calories or steps taken per day and are becoming increasingly popular due to the raising interest and awareness for a healthier lifestyle.

H2TRAIN provides technology-enabled societal benefits for facing the technological challenges that arise from evolving and future technologies such as IoT, AI, and edge computing. The challenges require advances in: Moore's law; functional building blocks; ICs; electronic performance; more-than-Moore devices; heterogeneous integration of functionality, among others.

II. Objectives and Ambition

Technological Research and Innovation are needed in the field of smart sensing technology, particularly for applications in healthcare monitoring, i.e., in local data analysis and interpretation because each human being is different. Obtaining accurate body parameters requires combining data from various sources. This task is challenging to handle using traditional modeling techniques or big data approaches, as they both require significant communication bandwidth, computational resources, and energy. Artificial Intelligence on the edge (Edge AI) and tiny machine learning (TinyML) [1] techniques applied on board of the single sensors or on clusters of them will be implemented in H2TRAIN to solve the identified technological challenge, ensuring adaptation to the different requirements and to the different individualities.

The rise of 2D material-based devices and sensors is driving growth in the health and sports market, fueled by factors such as: a) advancements in nanotechnology over the past two decades, b) increased use of wearable biosensors, c) growing demand for home-based point-of-care devices, particularly due to the COVID-19 pandemic and shortages of medical personnel, and d) greater focus from public authorities on remote health monitoring and diagnostics. The Internet of Things (IoT) plays a key role in creating new monetization opportunities and business models. The market is projected to grow from USD 300.3 billion in 2021 to USD 650.5 billion by 2026, at a CAGR of 16.7%. Embedded devices, which are widely used in point-of-care, home diagnostics, research, health, sports, environmental monitoring, and biodefense, dominate the biosensor market. Despite their potential, sensors' lifespans are often limited due to battery capacity. Therefore, energy efficiency and the implementation of efficient load balancing schemes for energy-gauge nodes are essential to maximize the lifespan of these wireless, constraint-oriented networks.

H2TRAIN focuses on the design of biosensors and their smart, non-invasive integration into textiles and wearable devices like smartwatches. The electronic design ensures effective real-time data transmission and processing in various ambient conditions, all while maintaining low fabrication and disposal costs. Advanced semiconductor fabrication, packaging technologies, and electronic printing techniques will be used to create textile micro-circuits, improving performance and ensuring cost-effective reproducibility. Nano-plasma methods will be employed to customize thread properties, enhancing skin compatibility, comfort, and durability. Further research and innovation, involving end-users from the early stages, will be crucial for ensuring high acceptance and broader market opportunities.

The goal of energy harvesting systems is to enable the continuous operation of connected devices without negatively impacting the environment. Energy harvesting, or power scavenging, involves capturing energy from external sources, storing it, and reusing it when needed. Its main purpose is to minimize energy losses and optimize the efficient reuse of energy. The growing interconnectivity of devices generates significant electromagnetic energy, particularly in the form of RF signals, which are abundant in urban areas. This provides an opportunity to recover, and store wasted RF energy efficiently. Rectennas, devices used for converting microwave frequencies, have achieved a record 90.6% power-conversion efficiency [5].

Driven by the increasing demand for real-time data monitoring and decision-making in personalized health and wellness, wearable sensor analytics platforms, such as e-textiles, are seeing high demand [6]-[7]. Their low cost, portability, user-friendliness, and rapid response times make them superior to traditional analytical instrumentation [8]. The wearable fitness technology market was valued at $45.5 billion in 2019 and is expected to grow at a rate of 74% by 2026, likely accelerated by the post-COVID-19 pandemic effects [9]. The pandemic led governments worldwide to impose strict travel restrictions, quarantines, and closures of workplaces, schools, and recreational activities, resulting in social isolation. This has triggered a global mental health crisis, with 70% of respondents in 63 countries reporting high levels of depression [10]. In response, the affected population is increasingly turning to remote sport training supported by IoT devices and cloud services, opening up significant market potential for the coming decade. However, the precision and reliability of many commercial devices still need validation, and ongoing R&D is required to enhance sensor performance, reduce invasiveness, and ensure professional and medical

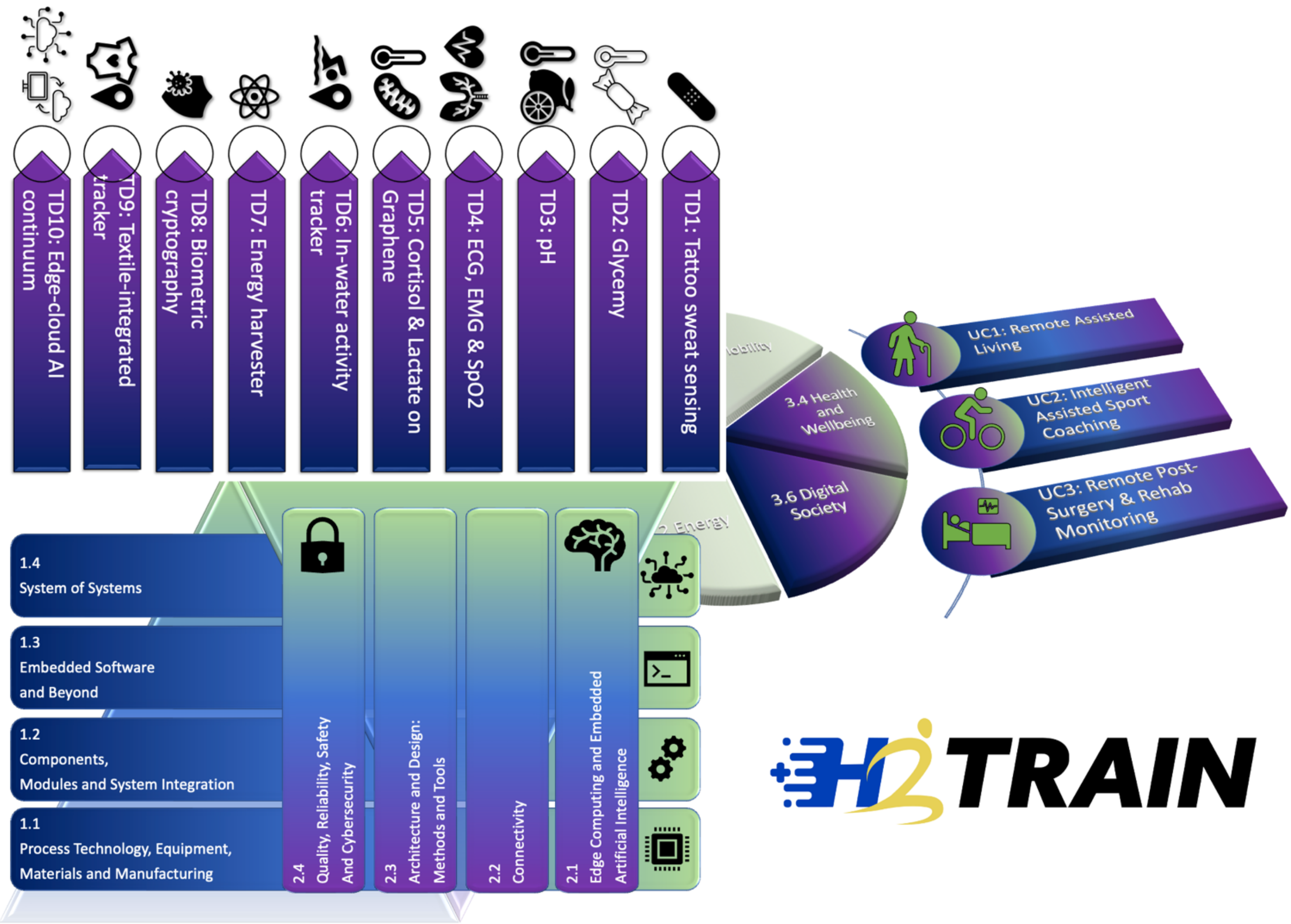

Figure 1. H2TRAIN conceptual schema. Foundational and cross-sectional technologies at the base of the pyramid. On to, the technology demonstrators from TD1 to TD9 and the edge-cloud AI continuum technology demonstrator TD10. On right, the three use cases in the ECS-SRIA application areas of digital society and health and wellbeing.

validation. Figure 1 illustrates the conceptual schema in H2TRAIN; for improving the outcomes for intervention in the growing personalized health & wellness, deployment of wearable sensors for monitoring health parameters is a practical solution, including stress monitoring.

A. *Sweat Sensing*

There are several molecules and ions in human sweat that, when excreted in abnormal amounts, may be an indication of a pathological disorder. Likewise, pH, C-reactive protein, lactate and cortisol are analytes present on the skin and excreted in sweat that may be detected and evaluated for diagnostic purposes [11]. Sweat lactate serves as a sensitive marker of tissue viability and may provide warning for pressure ischemia, reflecting the insufficient oxidative metabolism and a compromise of tissue viability. Cortisol is a well-known glucocorticoid hormone that is vital in physiological processes such as metabolism, electrolytic balance, and blood pressure regulation, all of which influence cognitive processes including working memory, sleep patterns, and mood [11]-[12]. Cortisol has also been recognized as a key biomarker of psychosocial stress, anxiety, depression, and mental health [13], but may also be used to assess strain of exercise sessions. It has been demonstrated that pH level of human sweat is correlated with the dehydration degree of the subject and its variations are correlated with the loss of Na^+ electrolyte during perspiration. pH is a useful parameter to monitor in sweat giving important information on health conditions including metabolic alkalosis, hydration, skin diseases, cystic fibrosis, among others [14]-[15]. The sensitive contemporaneous detection of those three parameters is very important for diagnostic reasons [16]. In the past two decades, advancements in nanomaterials development and basic research on sweat biology have enabled a slight but firm spreading in the utilization of the mentioned devices for monitoring specific proteins and hormones as potential biomarkers.

B. *Graphene Functionalization for Biomarker Sensing*

Graphene is a van der Waals nanomaterial that may be customized per thickness, bandgap, and electronic confinement requirements, permitting its use as a transducer. In H2TRAIN, the design and fabrication of flexible and monolithic biosensors for sweat-based health or exercise monitoring is included. H2TRAIN covers the development of 2D-material based devices and systems for energy-autonomous biosensing IoT nodes of stress and physiological endurance biomarkers based on C-reactive protein, cortisol, and lactate, respectively. This action brings 2D-materials technology one step further towards the integration in current IoT technologies and market. In H2TRAIN, 2D-materials for biosensing devices, energy harvesting, and storage supercapacitor are used for integrating sport and health activities on IoT applications as wearable technology. New prototypes for continuous stress monitoring based on C-reactive protein, cortisol and lactate biosensors in graphene are developed. 2D-materials for energy harvesting and energy storage supercapacitors with graphene electrodes are integrated in current mature semiconductor technologies for a wide range of application areas, for overcoming integration costs, functionalities and/or power consumption challenges.

C. *General Objectives and KPIs*

The Specific, Measurable, Achievable, Relevant, and Time-bound (SMART) objectives of H2TRAIN are outlined in Table 1.

Table 1. Specific, measurable, achievable, relevant, and time-bound objectives in H2TRAIN

Objective	Description
SMART1	Develop, prototype, and test a novel approach for human body sensing which features Artificial Intelligence-based data fusion from different sources of information enabling virtual sensing and aiming to reduce the error figures by 50% in comparison with existing solutions.
SMART2	Develop, prototype and test solutions for body-biomechanics monitoring that can assure a real-time data acquisition and transmission both in free air and in water (loss of data points < 25%, average transmission delay < 250 ms).
SMART3	Develop and test solutions for non-invasive body fluids monitoring to allow estimation of parameters like fatigue, and aerobic/anaerobic thresholds with an error figure of less than 15%.
SMART4	Integrate these solutions into smart-textiles with a factor of recyclability > 60% (weight of the whole bill-of-material) and able to withstand at least 100 washing cycles.
SMART5	Apply and validate these solutions in three business cases (health, recreational and professional sport) involving an audience of more than 1000 potential users for initial surveys and performing more than 100 test sets with a selected subset of them.

These objectives encompass the development of new hardware devices and modules for sensing biomarkers, energy harvesting and energy storage, as well as the creation of embedded system software development for IoT applications in sport, health, and remote assisting living. As a result of achieving these objectives, up to ten H2TRAIN technology demonstrators will be provided, showcasing the tangible results and innovations yielded by the project.

Key Performance Indicators in the field of IoT technology development (TDF) assess the performance of various constituent parts within proposed solutions. These evaluations are based on acceptance testing and requirements, spanning from the individual device level to the assembled system level. TDF has several dimensions such as: TDF1) devices and modules design, development, and test; TDF2) IoT platforms; TDF3) IoT system monitoring; TDF4) IoT functional design; and TDF5) IoT verification, validation, testing and certification.

III. EMBEDDED INTELLIGENCE SYSTEM FOR AIOT

In H2TRAIN, an interoperative hardware/software layer (see Figure 2) facilitates the transition between edge and cloud computing, forming an edge-cloud AI continuum, named TD10. This interoperative hardware/software layer is on top of the technology demonstrators (TD1-9), that are focused on human-centric technologies like Remote Assisted Living (RAL), Intelligent Adaptive Sport Coaching (IASC), and Remote Post-Surgery & Rehab Monitoring (RPS&RM). A demonstrator, TD10, acts as a fog layer, adapting communication protocols and requirements between the application level and the demonstrators.

The edge-cloud AI continuum enables low-level sensor components (TD1-9) to connect to the Internet, facilitating data movement from endpoint devices through IoT pipelines to central servers. This ensures that data is properly received and processed by subsequent steps in the connected system.

Smart network switches manage bandwidth and quality of service, optimizing communication channels in the network. Application layer is the hardware/software for providing capabilities as shown in Figure 3 which have been classified into a number of groups as: 1) information and communication technology, abbreviated as ICT; 2) ambience monitoring technology, abbreviated as Ambience; 3) digital twin technology; as Digital Twin 4) expert center technology, as Expert Center; 5) individual communication gadget, as Individual; 6) individual related communication gadget, as Individual Related.

All these applications are available through cloud-computing networks in comparison against edge-computing as is the case with technology demonstrators TD1-9. Note that technology demonstrator TD10 is an interoperative hardware/software layer between the application level and the rest of technology demonstrators TD1-9. TD10 incorporates smart switching capabilities for quality of service when TD1-9 technology demonstrators deliver data to main servers of the cloud-computing network. In addition, TD10 provides extra capabilities for AI/ML algorithms more beyond the embedded intelligence layer of the technology demonstrators (see Figure 6). The TD10 layer in H2TRAIN includes data compression to reduce network traffic load and supports Plug-and-Play (PnP) operation, allowing users to add or remove devices without manual configuration or hardware knowledge. It also includes an Intellectual Property (IP) security layer that verifies hardware/software licenses locally and remotely. TD10 facilitates the development of AIoT (Artificial Intelligence of Things) applications in health and sport by utilizing ultra-low power microcontrollers to push foundational technologies toward AI and IoT integration. This supports sensor data management and promotes edge computing over traditional centralized cloud data centers. Additionally, TD10 enables sensor fusion functionalities using microcontrollers based on ARM Cortex Mi and RISC-V processor architectures.

IV. Systems of Systems for AIoT

Description: H2TRAIN will not only develop an embedded intelligence system based on an ultra-low power microcontroller for pushing foundational technologies and 2D-material (2DM) technology toward IoT applications in sport; but also, will identify a sustainability end-to-end solution to provide continuous remote support in applications or use cases as: Remote Assisted Living (RAL), Intelligent Adaptive Sport Coaching (IASC) and Remote Post-Surgery & Rehab Monitoring (RPS&RM). The afore mentioned UCs belong to the domain of ECS-SRIA 2023 Health and Wellbeing and Digital Society application areas (see ECS-SRIA 2023 application areas).

A. *Remote Assisted Living (RAL)*

Remote Assisted Living (RAL) use case is founded in electronics components with embedded AI functions and real-time networking. The main foundational technologies are focused on edge computing and IoT devices, as air quality monitoring equipment, thermometer, pulse oximeter, glucometer, activity tracker, digital weight measurement equipment and blood pressure among others. As cross-sectional technologies, the use case includes edge computing and embedded artificial intelligence; connectivity and end-to-end trust covering the entire edge to cloud continuum.

B. *Intelligent Adaptive Sport Coaching (IASC)*

Intelligent Adaptive Sport Coaching (IASC) is another use case, in the application area of Health and Wellbeing and Digital Society of ECS-SRIA 2023, which is founded in electronics components, module and systems, embedded software and embedded intelligence, and introducing new biosensing devices based on graphene for stress monitoring. Another electronics components, modules and systems include heart rate, ECG and oxygenation measurement devices, glycogen and electrolytes sensing devices and localization and mobility trackers. Cross sectional technologies include edge computing and embedded artificial intelligence; connectivity and end-to-end trust covering the entire edge to cloud continuum.

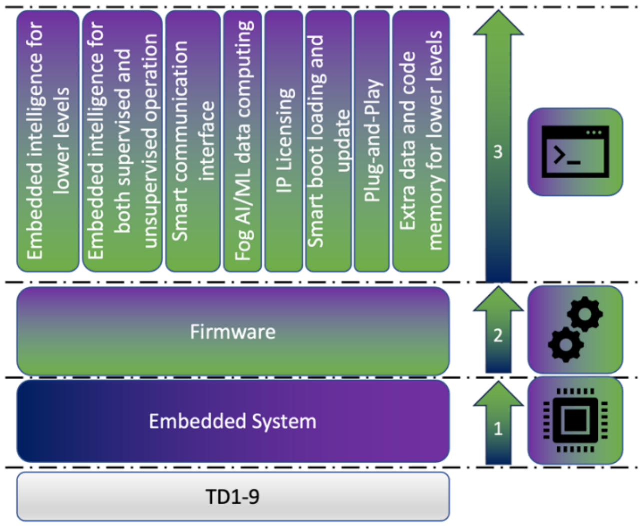

Figure 2. Intermediate layer: edge-cloud AI continuum.

C. *Remote Post-Surgery & Rehab Monitoring (RPS&RM)*

Remote Post-Surgery & Rehab Monitoring (RPS&RM) is also a use case in the application area of Health and Wellbeing and Digital Society of ECS-SRIA 2023. In this case, the electronics components, module, and systems include medical devices and equipment that are standards in post-surgery and rehab monitoring. Such equipment is integrated on the internet, by transforming it into IoT devices which have additional capabilities for edge computation. By introducing smart digital solutions which are driven by new technologies such as 5G, artificial intelligence with deep learning, virtual reality and augmented reality, new ways of how people and health professionals use and interact with these technologies are provided.

D. *System of Systems Approach*

The system of systems is for supporting with specific software tools the inclusion of the medical personnel, sport and coaching professionals, or the care givers of the elderly relatives as a function of the use case. Sustainability is addressed at technical level with the latest edge-to-cloud, AI and digital twin technologies, but also defines a new healthcare business model based on the P4 approach (predict, prevent, participate, personalize), putting people at the center and not limiting support to the patient but including all the fundamental actors (medical staff, social care givers, families, etc.) when considering societal sustainability.

E. Edge-to-cloud continuum integration

These use cases propose a new solution based on the concept of edge-to-cloud continuum, a Cloud-based solution exploiting Internet of Things (IoT) technologies, AI, and Edge Computing to provide remote home care and support to elderly people, both at home and in nursing homes. Operators can carry out routine operations remotely, relying on a rich amount of information collected from environmental and biological sensors, which are instrumental to monitoring and detecting early variations of parameters that, i.e., they may occur and have effect in the health and / or habits of elderly person. The solution also aims to monitor social relations and provide an evaluation tool to support operators in improving social relations of the assisted individual.

F. Application Layer Structure

Application layer is the hardware/software for providing capabilities as shown in Figure 7 which have been classified into a number of groups as: 1) information and communication technology, abbreviated as ICT; 2) ambience monitoring technology, abbreviated as Ambience; 3) digital twin technology; as Digital Twin 4) expert center technology, as Expert Center; 5) individual communication gadget, as Individual; 6) individual related communication gadget, as Individual Related. All these applications are available through cloud-computing networks in comparison against edge-computing as is the case with technology demonstrators TD1-9. Note that technology demonstrator TD10 is an interoperative hardware/software layer between the application level and the rest of technology demonstrators TD1-9.

G. Data Collection and Process Automation

For all the applications, i.e., the use cases Remote Assisted Living (RAL), Intelligent Adaptive Sport Coaching (IASC) and Remote Post-Surgery & Rehab Monitoring (RPS&RM); the application layer structure is similar, and this structure is introduced in Figure 7. Thanks to the collection and analysis of all these data, it is possible to automate some processes at home or within the nursing home, such as the handover between healthcare workers that occurs during shift changes, the management of drug reorders, the tracking of location of health equipment (wheelchairs, nebulizers, oxygen pumps) and perform predictive analysis. Figure 7 illustrates the architecture of the proposed solution, where sensors will be installed in sportsman, patients, or elderly people's homes or in the nursing homes together with edge computing devices which will be connected to a centralized system that collects and processes information in nearly real time.

H. Digital Twin Technology Implementation

The objective of solution is also to provide to professional, medical staff, caregivers, health, and social care workers a digital twin that helps to automate checks and monitoring of patients, sportsman, or elderly people at home. The digital twin implements a virtual representation of an operator who is informed and updated with nearly real time data which are processed with AI and machine learning techniques to help detecting possible problems and alerts and suggest possible decisions and actions to be taken in case of problems and emergencies. The digital twin will be deployed through an application which is devoted to the medical staff and operators. The proposed solution will also provide to elderly people a simple application that establishes the connection between the individual and the operators/caregivers and relatives and will allow to visualize data collected from sensors and related alerts, e.g., high level of CO2, gas leakages, humidity level, drugs prescription time, among others. Finally, the solution will also be adopted in the case of small communities where several units, nursing homes and monitoring centers for the elderly, will be able to send the data to a medical center where a specialist can analyze them in real time.

V. CONCLUSIONS

H2TRAIN is developing an integrated system that combines edge computing, AI, and IoT to provide continuous remote support for applications like Remote Assisted Living, Intelligent Adaptive Sport Coaching, and Remote Post-Surgery Monitoring. These use cases focus on real-time health monitoring and personalized care for elderly people, athletes, and post-surgery patients.

The project integrates ultra-low power microcontrollers and 2D-material technologies to push the boundaries of IoT applications, with an emphasis on sustainability, edge-to-cloud data flow, and embedded AI. It utilizes edge-to-cloud continuum to monitor vital signs and environmental conditions in real-time, ensuring early detection of health changes and improving quality of life through predictive analytics.

Key innovations include digital twin technology, which provides a virtual representation of individuals, updated with near-real-time data to help healthcare professionals and caregivers make proactive decisions. The system also automates routine processes, such as drug reordering and health equipment tracking, improving efficiency in care delivery.

Ultimately, H2TRAIN aims to revolutionize healthcare by creating a system of systems that engages all relevant stakeholders (medical staff, caregivers, families) and supports a P4 approach—predict, prevent, participate, personalize—ensuring that healthcare is both sustainable and centered on the individual.

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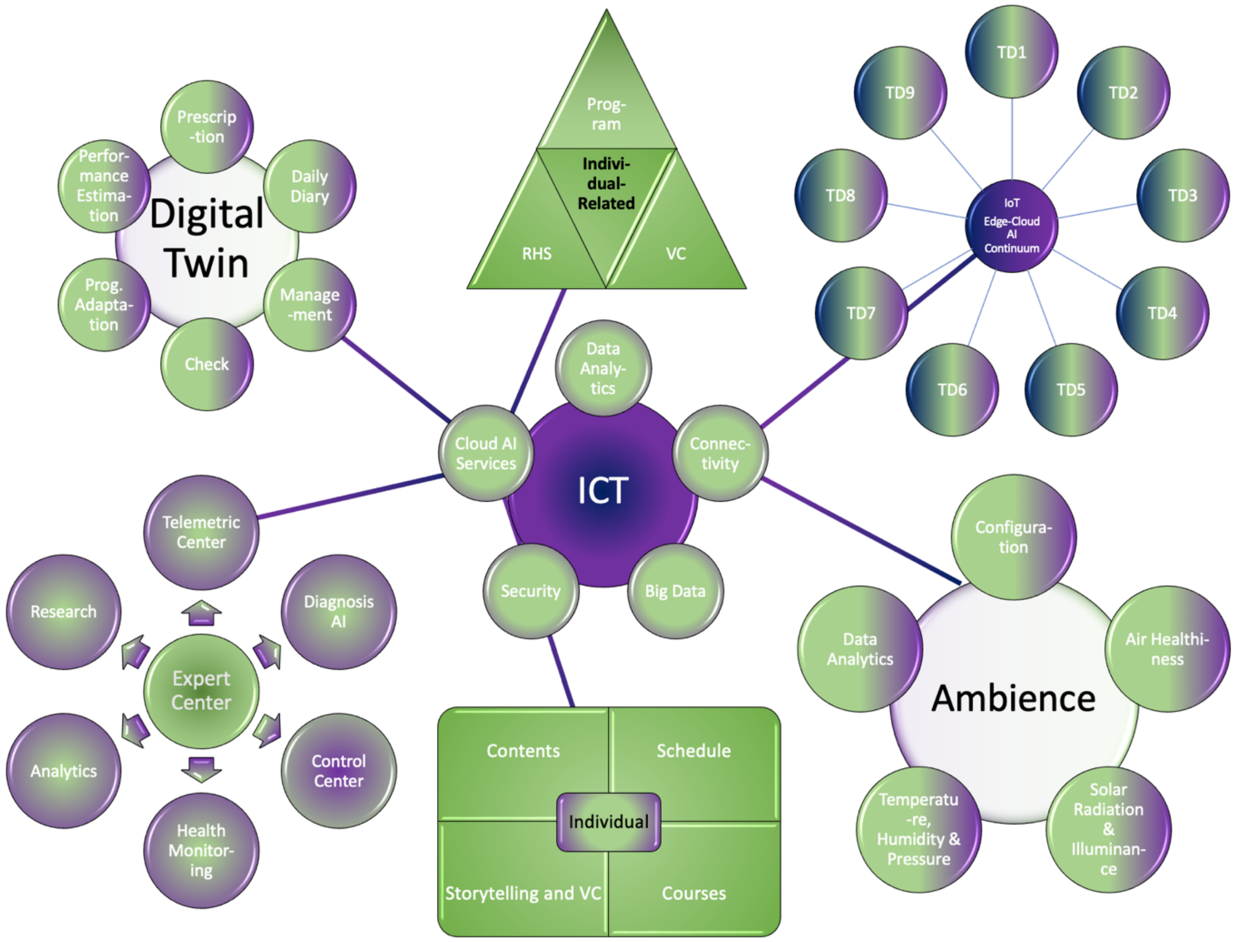

Figure 3. H2TRAIN conceptual schema for system of systems. The application layer for use cases Remote Assisted Living (RAL), Intelligent Adaptive Sport Coaching (IASC) and Remote Post-Surgery & Rehab Monitoring (RPS&RM).

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