TETRAMAX success stories

Highlights of Technology Transfer Experiments in Customized and Low-Energy Computing

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tetramax

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Stimulating technology transfer at European scale

by Prof. Rainer Leupers

In 2017, within the EU Horizon 2020 framework, we started an ambitious meta-experiment in the form of an Innovation Action: Technology Transfer via Multinational Application Experiments (TETRAMAX, Grant Agreement no. 761349). Would it be possible to stimulate hundreds of actors in European academia and industry to engage more intensively in tech transfer activities, with a focus on customized and low-energy computing? Our hypothesis, based on experiences with a predecessor project (TETRACOM), was that this could be enabled by a blend of measures, ranging from technology brokerage facilities and matchmaking events to organization of co-funded Technology Transfer Experiments (TTX). We addressed a matrix of key application domains, such as automotive, communications, or healthcare, as well as different Technology Readiness Levels, and we issued a series of open calls for cross-border TTX across the EU and its associated countries.

Looking back, we can now proudly state: Mission accomplished! Altogether, we enabled 63 TTX of various flavors selected among 250 proposals submitted to our open calls. In the first place this means that 63 specific technologies (e.g. some software or hardware IP) matured from research to new or improved products, which in turn enable energy or cost savings, better user experience, or higher safety. However, there are also many economic sustainability aspects. We have applied a multitude of numerical Key Performance Indicators to also measure the long-term impact, e.g. in the form of new jobs created, revenue increase, or follow-up investments acquired. Our surveys indicate that quite many of our clients experienced such benefits beyond the horizon of single TTX.

Some selected “high-performance” TTX are featured in this brochure with their individual success stories presented in a compact form. In case of further interest, don´t hesitate to get directly in touch with the contributors. You can find all funded TTX and many more TETRAMAX results at www.tetramax.eu.
There have been many contributors to the TETRAMAX experiment as a whole, and it has been a pleasure and honor for me to coordinate this project. In particular I´d like to thank my many friends and colleagues from the consortium, the fantastic project office team, and the various Project Officers that supported and encouraged us from the EC side.

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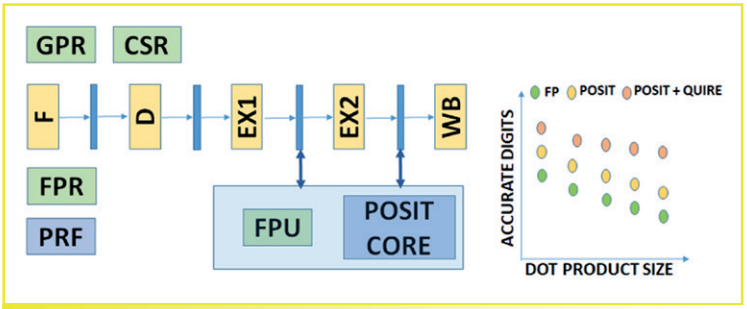
ERIC: Accuracy Meets Latency

Efficient and Accurate Realization of Matrix Inversion Using Posit Arithmetic for Communication Systems

Problem and solution



Application-oriented airthmetic (a) posit arithmetic core in a RISC-V processor, (b) accuracy of dot-product using posit and quire

Modern communication systems require accuracy in computations while power, area, and latency are constrained. Ultimately, meeting these requirements in a non-flexible System on Chip (SoC) is challenging due to the engineering and manufacturing costs involved in the design and development. Furthermore, many of the operations carried out in a communication system are matrix operations, for example, QR factorization, singular-value decomposition, FFT, and IFFT. This experiment provided a solution for accelerating high-accuracy matrix computations for Nokia Bell Labs SoCs, where a new number format scheme called posit arithmetic was incorporated into a RISC-V-based SoC.

The Institute for Communication Technology and Embedded Systems (ICE) has developed a posit arithmetic hardware solution and corresponding enabler technologies. The hardware prototype involves a RISC-V processor where a posit arithmetic core is tightly coupled to the RISC pipeline. The framework supports a special data type called quire that allows a series of accumulations without rounding to maintain a very high accuracy of the computations such as dot products. Furthermore, the framework is highly configurable and has a stable compilation toolchain, allowing for seamless design space exploration. In the experiment, ICE demonstrated the impact of posit arithmetic on matrix computations for various data widths and problem sizes that Nokia Bell Labs consider in their next-generation SoCs.

Role of TETRAMAX as Digital Innovation Hub

Nokia Bell Labs in Belgium was actively searching for a partner that has the technology to adopt the new posit number format and has a TRL of at least 5. Nokia Bell Labs and ICE were discussing a possible collaboration that enables them with the posit arithmetic technology developed at ICE. In the meantime, TETRAMAX as a DIH acted as a vehicle that allowed this technology transfer. The TETRAMAX project supported the staff at ICE that elevated the TRL of the technology and generated the desired data to be adopted by Nokia Bell Labs.

Impact

The received experimental data enables Nokia Bell Labs plans to improve the accuracy of the solution by two orders of magnitude while providing a latency benefit of 2x to meet the real-time requirements of their SoC platforms. Also, 20% power and 15% area savings are observed at the minimal loss of accuracy for reduced bit-width operations. After further experimentation, Nokia Bell Labs plans to incorporate the posit arithmetic hardware in their future-generation SoCs. A patent and a publication are underway for the experiment. The TRL is raised from 5 to 7.

RWTH AACHEN UNIVERSITY

NOKIA Bell Labs

Main contact

Technology partners: RWTH Aachen University, Institute for Communication Technologies and Embedded Systems, Germany – Nokia Bell Labs, Belgium
Principal investigators: Farhad Merchant, Manil Dev Gomony

TETRaWIN: Smart-Sensing of fresh and frozen fish

Technology Transfer of computational-Rfid Wirelessly-powered IoT Nodes

Problem and solution

This experiment has transferred the renowned experience and know-how of the University of Salento in the matter of IoT technologies, like C-RFID (Computational RFID), to the SME partner Spica Sustavi d.o.o.. Specifically, an UHF RFID sensing platform has been developed for cold-chain applications. The idea behind has been to realize an embedded solution equipped with a specifically designed robust antenna, capable of not only tracking the fish box, but also continuously checking its temperature and generating both local and remote alerts according to a specific smart monitoring algorithm. The proposed tag has been designed with the aim to allow the tracking of fresh and frozen fish along with its temperature monitoring in order to control the product in each step of the cold chain.

During this experiment, a functional solution that exploits C-RFID as one of the most promising IoT technologies has been studied, designed, realized, and transferred.

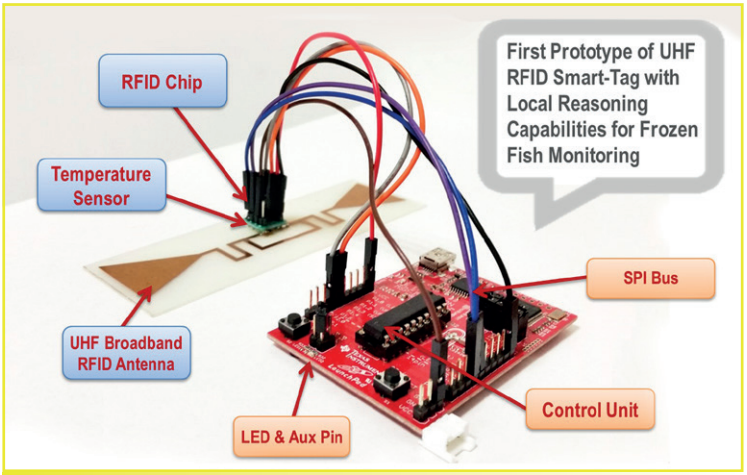
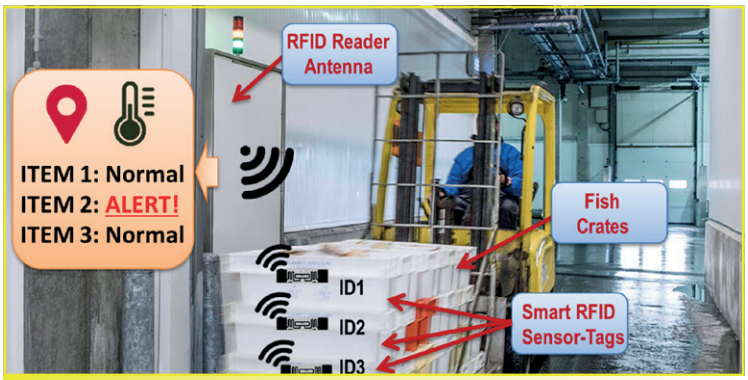


Photo of the first prototype of the C-RFID device realized for validation purposes.



Working principle: once close to an RFID checkpoint, the tags inform the system about the temperature history of the fish boxes.

Role of TETRAMAX as Digital Innovation Hub

The TETRAMAX consortium played a crucial role not only because it considerably supported the activities for a successful know-how transfer from the research center (University of Salento) to the industry (Spica Sustavi d.o.o), but also because it generated the opportunity to create the contact between the two entities, by fostering an important business opportunity. Moreover, TETRAMAX, acting as Digital Innovation Hub, provided to the partners both technical and business coaches whose constant support has been a very appreciated added value.

Impact

This new developed device enables the possibility for the SME partner Spica to satisfy a growing demand for IoT solutions in the fresh and frozen food supply chain framework. Moreover, the final customer will presumably benefit of a reduction of the maintenance costs (i.e., no periodic battery changes) as well as a wastage reduction (20%) through the smart temperature monitoring of fish and an accuracy increment of goods delivery.

UNIVERSITÀ DEL SALENTO

spica

Main contact

Technology partners: University of Salento, Italy - Spica Sustavi d.o.o., Croatia

Principal investigator: Luca Catarinucci

PROMIoTOR: Deep Learning for a more sustainable agriculture

Low-Power Internet of Things and Artificial Intelligence for the sustainability of processes in Smart Farming

Problem and solution

PROMIoTOR System under operation in Cyprus agriculture fields

Nowadays, in a highly competitive and globalized food market, consumers have more options to choose, being increasingly worried about how the products they consume are produced and how the production impacts the environment with respect to water, carbon footprint, or people's health. Nonetheless, there are different pests and plagues that negatively affect the agricultural production, provoking losses in harvests and increasing production costs because of the use of pesticides, whose doses must be limited while balancing yield and sustainability. EMBIO's customers are farmers that need to provide their consumers with a differentiated green product, following precision agriculture methods that respect environment and health. In this sense, TAMIC provides Low-Power IoT agrometeorological stations for measuring different parameters (rain, temperature, humidity, leaf wetness) in crops in real-time to build precision agriculture applications. In this project, the AIR Institute applied its know-how in Deep Learning and Recommender Systems to gather data from TAMIC's Low-Power IoT stations to feed AIR's DL-based sustainability predictors, providing EMBIO's customers with the sustainability indicators of the conditions involved in the farming processes they follow. Consequently, EMBIO's customers are given the ability to modify these processes based on the indicators to provide consumers with greener products.

Role of TETRAMAX as Digital Innovation Hub

The TETRAMAX DIH assisted in the development of the PROMIoTOR project by providing support at the technical and result-exploitation level. At the technical level, its assistance helped to improve the end-user experience of the platform. On the other hand, the DIH helped to analyse other competing solutions and to identify possible distribution channels in other countries, improving the business plan.

Impact

According to Eurostat, there are countries in EU-27 where the use of pesticides has been increased during last years. Although Spain and France are world leaders in ecological viticulture (FiBL, 2014), these trends do not seem similar in the other crops. The largest organic producers in the world are India, Ethiopia and Mexico, and the largest organic agricultural lands are in Australia, Argentina and United States. Nonetheless, the highest per-capita consumers are in Europe (Switzerland, Denmark and Sweden). This means that large EU-27 producer countries take the risk of losing the opportunities with high-value organic and ecological food as they must compete worldwide for the European consumers. In this sense, the PROMIoTOR platform will help EU farmers follow a sustainable agricultural methodology and allow them to provide worldwide consumers with the measured parameters and indicators taking part into the farming production chain.

One of the PROMIoTOR key impacts, relevant for the partners TAMIC and EMBIO, include one improved product (Low Power IoT station) and one new product: deep learning based sustainability platform, potential to achieve 20% savings in water, energy, and phytosanitary in agriculture.

Main contact

Technology partners: AIR Institute, Spain - SK EMBIO DIAGNOSTICS LTD, Cyprus - TAMIC SL, Spain

Principal investigators: Juan M. Corchado, Constantinos Loizou, José M. Caballero



H-BEACON: Signal strength change to detect soil humidity

Soil Humidity Prediction: the Beacon Approach

Problem and solution

Soil humidity prediction is an essential feature of smart agricultural systems used to manage livestock and crops precisely. Moreover, smart cities can benefit from optimal water consumption in green areas. To enable those smart functionalities and prolong battery life, it is crucial to have a low-power sensory system to sense soil humidity, especially in remote areas where the battery replacement is a demanding task. The sensing feature must also be cost-effective, aiming to reduce initial costs for investors to encourage its implementation.

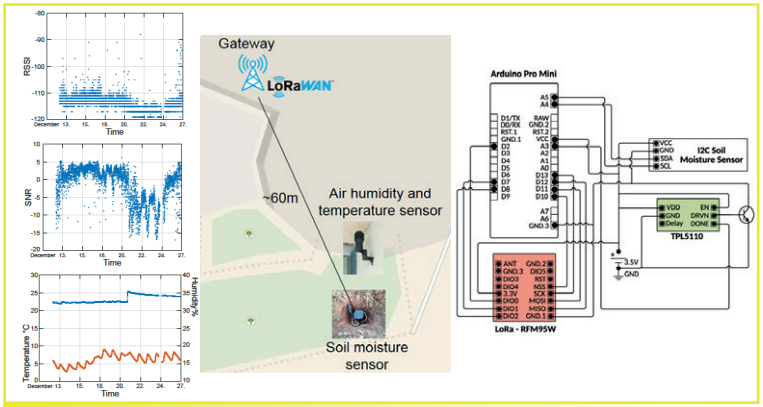


Figure 1. Snapshot of RSSI and SNR signal captured (given in a.) on LoRaWAN gateway (for setup given in b.) from soil moisture sensor, along with I2C sensor measures of soil humidity

It is a well-known physical property that water influences the propagation of radio waves through signal attenuation. To extract soil humidity information from the signal strength change, the University of Split, FESB, deployed the LoRaWAN architecture to read sensor data from different sources: soil sensor, atmospheric data (air humidity and temperature). In contrast, the air pressure was retrieved from the data available at the State Hydrometeorological Institute. It was assumed that atmospheric data could enhance the estimation method since it describes surrounding conditions more accurately.

Two types of software for data visualization were built to present and easily manipulate the data in the ML domain. The first one is a professional-like tool that makes statistical analysis easier in terms of better understanding how to prepare data for ML techniques. The second one is more user-friendly, with real-time data. It allows downloading the sensor data in CSV format, it can control sensor wake-up time, and it alarms the users when values reach user-defined thresholds. Furthermore, it integrates the service that can call the ML model and present detailed data.

Role of TETRAMAX as Digital Innovation Hub

Without the support of TETRAMAX, it would not have been possible to verify the capabilities of the technology and elevate the TRL, which in case of this experiment changed from 3 up to 5. The support provided a perfect match between the academia and the entrepreneurial world. The project outcomes were described in several impacted research publications, while the results created a product, which is ready for scaling up and attracting new investments. This recognition created new a pool of opportunities for both commercialization and new research.

Impact

As there is a need for an alternative soil sensing mechanism for the measurements, the newly developed innovative technique enables:

- customer related reduction of risks in terms of the nodes deployment, since the solution is fundamentally less expensive than others on the market (since it does not have a soil sensing probe);
- cost effective/prolonged battery lifetime solution for soil monitoring and consequently optimal automatic irrigation system;
- increased usability

The business case showed that a 20 EUR reduction in price per device, since the soil sensor probe is not required, and 30% reduction in energy consumption, depending on the frequency of data transmission was possible.

Main contact

Technology partnes: University of Split, FESB, Croatia
Principal investigator: Petar Šolić

CARROTS: Monitor your plants and build a smart, healthy garden

Cooperative architecture for gardening with open monitoring systems (CARROTS)

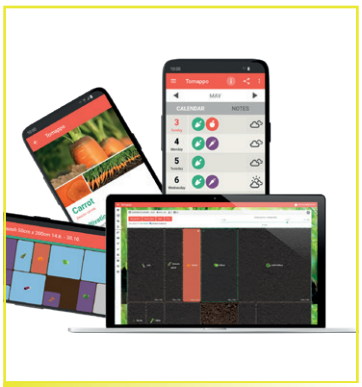
Problem and solution

What hobby gardeners have in common is their enthusiasm for gardening and love for plants, but unfortunately also lack of time and knowledge on what their plants need. Thus, many gardening enthusiasts need help to grow and cure their plants. The Lifely's smart sensors called Agrumino allow continuous measuring of soil moisture, temperature, and brightness. These sensors are optimized for low energy consumption and include a rechargeable battery charged via USB. Within CARROTS, these sensors were adapted for use with the Tomappo mobile and web app for hobby vegetable gardening. This added a new IoT dimension to the Tomappo app, leading to a better product for users and new revenue streams for the company receiving the technology, while at the same time benefitting the owner of the technology by providing a use-case for their sensors in a new domain.

Therefore, the web and mobile platform supports gardeners to build a smart garden and to identify the needs of their plants.

The CARROTS sensor, tested by a hobby gardener

CARROTS garden sensor in its natural habitat among lettuce sending data about soil moisture and temperature over WiFi to Tomappo web and mobile app.



Tomappo web-based garden planner and mobile application that guides gardeners through the whole gardening season - from planning to enjoying the produce from their garden.

Role of TETRAMAX as Digital Innovation Hub

TETRAMAX facilitated the cooperation, and hence, the integration of Agrumino wireless sensors with the Tomappo gardening platform. Agrumino sensors were improved with reduction in energy consumption (35%), cost reduction of manufacturing (18%), and customised for outdoor use. The TRL increased from 6 to 7. The Tomappo web app was upgraded with automatic planning that produces an optimised garden plan in just a few clicks, taking into account garden size, companion planting, and number of persons in the household is currently considered for further discussions.

Impact

The project contributed to the growth of Tomappo in the last year, resulting in 11,000 new registered users, doubling the number of Tomappo PRO licenses sold, and 12 new B2B partnerships. A serial production of the sensor with a large producer of gardening equipment is currently considered for further discussions.

Main contact

Technology partners: Lifely s.r.l., Italy - Proventus, računalniške storitve, d.o.o., Slovenia
Principal investigators: Antonio Solinas, Vanja Blazica

CORONA: Economy in Manufacturing Environments

Distributed Ledger Technology Based Collaborative Robotics for Low-Energy Machine Economy in Manufacturing Environments

Problem and solution

The technology transfer experiment "CORONA" successfully combined Distributed Ledger Technology (DLT) with collaborative robotics and low-energy microcontrollers, integrating these core technologies on a DLT platform specifically designed for an Internet of Things (IoT) manufacturing environment. The challenge was that machines and factory assets such as collaborative robots are only equipped with proprietary control units used for executing robot operations.

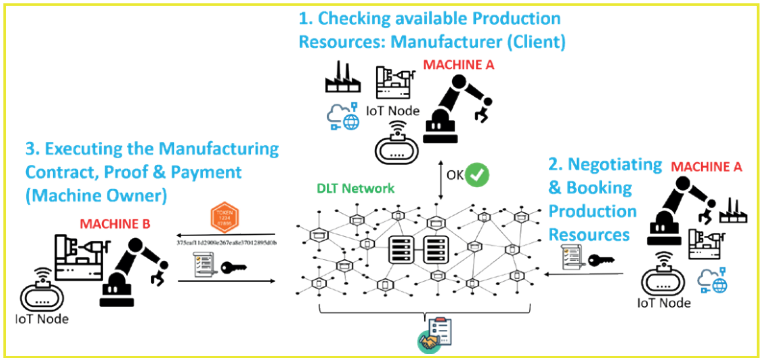


Illustration of the corona machine economy use case.

Sensing capabilities of robots, machines, and other equipment which go beyond safety purposes and are at the same time energy-efficient are still rare. Beyond this, the autonomous exchange of information between robots and machines in manufacturing environments while maintaining economic relationships with the participants of a manufacturing ecosystem imposes challenges, such as security, decision making, and distributed coordination.

A comprehensive experiment (proof-of-concept) has been conducted to tackle the previous problems, which executed an open-source protocol that facilitates Machine-to-Machine (M2M) interactions, including secure data transfer and real-time transactions. The experiment introduced an industry-compliant low-energy μC connected to a 3D-printer and a virtual robot, combined with a coherent DLT approach embedded in a private Ethereum network to enable transactions between machines and execute smart contracts. The pursued industrial use case in CORONA was about autonomous booking of production resources.

Role of TETRAMAX as Digital Innovation Hub

Thanks to the support of TETRAMAX as a DIH, and the beneficial collaboration between the technology provider and receiver, Pumacy was able to reinforce their position as a Platform-as-a-Service provider, while the University of Ljubljana benefitted from the alignment of their technology platform to further industrial use cases. Specifically, we see tangible benefits in extending the CORONA solution to other application fields on behalf of machine economy/protocol economy scenarios. This pathway will definitely make DLT and low-power computing more attractive and feasible for industrial customers. In order to stimulate the visibility of the experiment results in the post project phase, a demonstration video has been produced by TETRAMAX for marketing purposes.

Impact

Within CORONA experiment, a DLT network and smart contract infrastructure based on a private Ethereum network characterized through fast transaction and energy efficiency has been successfully set up and validated. As a machine economy scenario, an autonomous booking of production resources between stakeholders represented as machines, and a delivery vs. payment business model has been demonstrated. The results will impact other machine economy use-case scenarios, which address the utilization of physical assets (e.g. machine leasing), where additional business models can evolve (e.g., pay-per-use). In this way, traditional manufacturing concepts can be leveraged by providing the backbone for offering "manufacturing-as-a-service", where manufacturers pay the machine owners (e.g., micropayments) based on their use of each machine. This reduces cost and overhead of owning a factory of their own.

Univerza v Ljubljani

PUMACY TECHNOLOGIES

Main contact

Technology partners: University of Ljubljana, Slovenia - PUMACY TECHNOLOGIES AG, Germany

Principal investigators: Pierre Kirisci, Matevz Pustisek

CLEC-PV: Making photovoltaic investments more secure and trustworthy

Blockchain Technology for Photovoltaic Power

Problem and solution

In the renewables sector, support for Power Purchase Agreements (PPA) is needed. A PPA means that the producer must build a Photovoltaic (PV) Plant to generate energy while the customer has to buy this energy. Assurance in the traceability of production is missing, and no systems provide an independent measurement and verification process for the PPA contract signatories.

Moreover, there is no reliable, independent verification between reality and the corresponding invoice where the agreed price is reflected. The experiment has created a cost-efficient solution to manage PPAs by integrating Blockchain technology, CLEC sensors technology, and an energy management platform to solve this problem. The major components are:

1. Bettergy users (PPA signatories) sign up to EnergySequence and manage the PPA, confirming the transactions with their Blockchain identity
2. EnergySequence allows the authenticated signatories to interact in a decentralized manner with the Smart Contracts using their Blockchain credentials.
3. Data loggers installed on-premises gather and send data to the Blockchain through ReMoni CLEC sensors technology.
4. Then, the related contract clauses are automatically verified in a decentralized way.
5. PPA signatories have two sources of information, EnergySequence and Blockchain, for maximum security and trust of the renewable investment made.

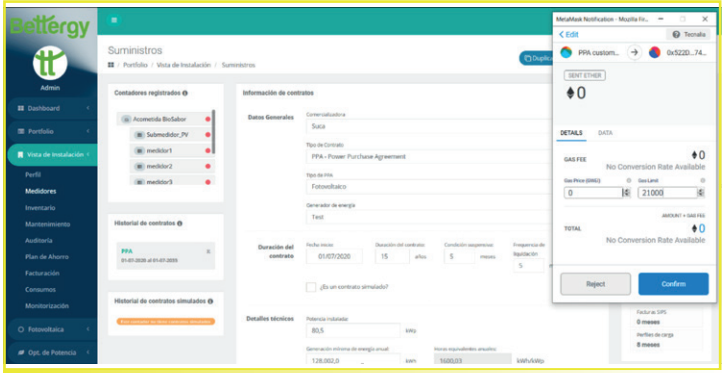


Figure 1. EnergySequence platform asking for signing the transaction in the Blockchain when the producer creates a PPA contract.

Figure 2. A PV plant build in the roof of a parking area of a real customer that uses the CT-clamps sensors from REMONI in a fully Blockchain integrated monitorization instance.

Role of TETRAMAX as Digital Innovation Hub

The TETRAMAX-enabled experiment has provided valuable benefits for all partners. Revenue opportunities are increased by attracting new photovoltaic producers and consumers with concern for traceability and trustfulness, providing them with an easy-to-install monitoring solution for both energy production and PPA clauses validation along the project. The transfer of technology from partner Tecnalia to the partners has been very positive, adding significant value to the product via Blockchain technology, while at the same time minimizing R&D investments.

Impact

The integration of the Blockchain technology, the Clamp-on IoT sensors, and the energy management platform provide a new technology product that makes the PPA management easier, cheaper, and more secure. PPA clauses and prices are now managed in a reliable way. One can close automatic balances based on the amount of energy generated registered in the Blockchain. In addition, the violations of the current PPA contract clauses are controlled in a decentralized way.

Main contact

Technology partners: TECNALIA, Spain - ReMoni A/S, Denmark - BETTERGY S.L., Spain
Principal investigator: Yesnier Bravo Garcia

BLEUN: Low Energy Urban Networks

Crowd-Sourced Mobility powered by BLE technology

Problem and solution

Global Navigation Satellite Systems (GNSS) (most commonly GPS) have proven to be insufficient for many geo-location use cases and purposes today. As an alternative, the BLEUN experts have found that the triangulation of Bluetooth Low Energy (BLE) signals in combination with WiFi signals offers a possibility to achieve ultra-accurate geo-location and allows for hassle-free tracking. The BLEUN experiment conducted field tests and two proofs-of-concept to find out the highest accuracy they could possibly achieve and to test the hardware involved in the system extensively. Taking into account lessons learned during the previous steps, the technology was fine-tuned and optimized.

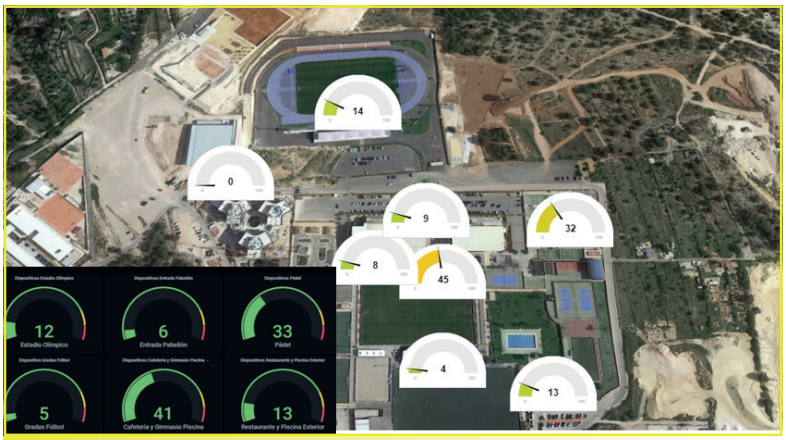


Figure 2: BEEHIVE technology dashboard of Camillo Cano Sports City, La Nucía, Spain (Elected best Sports City of all times by the European Parliament)

Role of TETRAMAX as Digital Innovation Hub

TETRAMAX aided the consortium during the setting up, piloting, and evaluation of the technology by providing key business contacts and mentoring at the right time. Without the funding of the Digital Innovation Hub, the technologies' market readiness would have been further delayed.

Impact

During the field test, energy consumption was reduced by 8.76% compared to traditional GPS trackers commercially available today. Furthermore, an impressive range of up to 20 metres around any Bluetooth beacon and a communication range of 400 metres were observed. Most importantly, 60+ new business contacts worldwide helped one of the consortium partners to launch two new products to the market: a 360° electro-mobility service for luxury and eco hotels called Movere[1] and a sensor network called Beehive[2], based on both BLE technology and WiFi signals to provide managers of large facilities with business intelligence

[1] https://www. movere.world/
[2] https://www.thebeehive.world/

Main contact

Technology partners: Intelligent Parking S.L., Spain - Etelätär Innovation O.Ü., Estonia - Serveis de Maquinaria Banyolina S.L.,Spain
Principal investigators: José F. Papí, Friederike L. Kühl.


TETRAMAX consortium partners

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