NORDIC Semiconductors Competition
Connect for Good: Low Power Sustainability Challenge

https://www.nordicsemi.com/Nordic-news/2023/04/nordic-semiconductor-and-wevolver-launch-competition

Subject: “NordiCube©2023” project proposal by PANGAEA R&D start-up

Thomas T. Thomaidis, PhD - Pangaea R&D CTO, Georgia V. Panagopoulou, MBA - Pangaea R&D CEO, Vasilis Vorrias, - Pangaea R&D Technical Manager

Proposal submitted by 10th of October 2023, Thessaly - Greece

PANGAEA R&D

PANGAEA RESEARCH & DEVELOPMENT
VAT: EL801795770, Reg. No:163482340000
Address: E. Katsigra 1, PC 41222
http://www.pan-gaea.gr

Contact Person: Vasilis Vorrias,
email: vorrias@pan-gaea.gr
tel.: +30.6941576699

PANGAEA R&D

Connect for Good: Low Power Sustainability Challenge

NORDIC Semiconductors Competition

“NordiCube©2023” proposal

Table of Content

PANGAEA R&D PC, E. Katsigra 1, PC 41335, T +30.2413025570 E: info@pan-gaea.gr W: pan-gaea.gr

1. Introduction

The current **NordiCube design proposal** reflects the potential of the startup **Pangaea Research & Development** Team to create innovative **Low Power** IoT **Wireless** products supporting the United Nations Sustainable Development Goals **towards Sustainability.** Emphasis has been given on four particular goals that relate to cities and sustainability - **Goal 7:** Affordable and clean energy, **Goal 11:** Sustainable Cities and Communities, **Goal 13:** Climate Action and **Goal 15:** Life on Land.

2. Pangaea R&D IKE

Pangaea R&D is a newly established private company based in Thessaly Region - Greece.

The vision of Pangaea R&D is a modern multidisciplinary approach towards the development of intelligent and environmentally friendly solutions in accordance with the current state of the art industrial developments. Among Pangaea R&D goals are the development and implementation of technological innovations and know-how, in the modern rural and urban areas, through collaboration with academic and research institutes, via networking, coordination and collaborative actions of complementary disciplines, thus covering the fields of **smart agriculture**, **smart cities**, **maritime informatics**, **telematics** and **innovative production technologies**.

Our vision is to embed the new features/capabilities of **nRF9160** (Nordic Telecomunication Technologies) as a compact **low power SiP** with integrated LTE-M/NB-IoT modem and GNSS, with advanced processing and security capabilities, accessible and easy to use to a single device low power cellular IoT design, namely **NordiCube**.

3. IoT Collaborative Ecosystems

Pangaea R&D has been utilizing various innovative IoT and technological ecosystems, in order to provide state of the art services and products in the fields of smart agriculture, smart cities, maritime informatics, telematics and innovative production technologies, collaborating with public and private bodies, as follows:

Research Laboratories:

- NITLAB - Network Implementation Test Bed Laboratory, University of Thessaly, Greece (https://nitlab.inf.uth.gr/)
- Laboratory of Agronomy and Applied Crop Physiology, University of Thessaly, Greece (http://agr.uth.gr/en/?page_id=66)

PANGAEA R&D PC, E. Katsigra 1, PC 41335, T +30.2413025570 E: info@pan-gaea.gr W: pan-gaea.gr

- **Laboratory of Pomology, School of Agricultural Sciences**, University of Thessaly, Greece, (http://agr.uth.gr/en/?page_id=74)

Research Programmes:

- **FED4Fire – Field Research on Precision Agriculture With LoRa (PAWL experiment)**: Pangaea R&D as an IoT solutions provider for precision agriculture, is supporting farmers and agronomists all over Greece. The conducted PAWL demo experimentation research (2021) for open field precision agriculture applications investigated the performance of LoRa (low-power wide-area network modulation technique) vs to ZigBee based solutions, towards optimize the cost effectiveness and reliability of the provided IoT solutions on various aspects like coverage, throughput and energy efficiency. (https://pan-gaea.gr/fed4fire/)

Technology vendors and enterprises:

- Polytech Educational Systems SA, Design and Development of a wide variety of Educational Laboratories (https://polytech.com.gr/).
- **GRIDNET sa**, Pioneer Developers of communication and internet technology solutions, Wireless Communications, Software-Defined Networking, Sensors Network and Energy Management, https://gridnet.gr/
- **ARI Simulation - Applied Research International**, sophisticated simulation and virtual reality training solutions for the marine, energy, construction, airport and defense industries. ARI designs and develops high-specification complex simulation systems **(**https://arisimulation.com/)
- **SKLAVENITIS sa** - Sklavenitis Group owns approx. the ⅓ of the Greek retail market, turnover (2021) 3,98 Billion Euros, 36,000 employees serve 530,000 customers, over 523 private stores. (http://www.sklavenitis.gr/profile/index.html#/slide/2)
- **Kronos SA** a private, 100% export oriented company, considered the leader in the Greek canning fruit industry, the largest producer in Europe and among the top five players in the world regarding canned peach. (https://www.kronos.com.gr/company)
- **3D SA** is a Greek private company since 1976. The company provides custom made services and applications on Weather Modification Programs. 3D sa offers a distinguishing range of services that rightfully makes it unique in Europe and one among the four most recognized companies worldwide specializing in Weather Modification Applications, https://www.3dsa.gr/en/
- **ISONET Ltd** (Fezatel Group) is an African (Uganda) Telecommunication company, operating over a wide area of Uganda nation, managing Communication and IoT projects (https://fezatel.com/)

In this proposal particular emphasis has been given into AgroNIT, a precision agriculture IoT based ecosystem, as follows.

PANGAEA R&D PC, E. Katsigra 1, PC 41335, T +30.2413025570 E: info@pan-gaea.gr W: pan-gaea.gr

4. Case Study AgroNIT: A Game-Changing Smart Farming IoT Ecosystem

AgroNIT is a powerful IoT-based ecosystem developed by NITLAB (valorising research results of a series of European and National research programmes) for the distributed monitoring and field data collection enabling real-time decision support. The system is composed of three interactive components: **1) the edge system; 2) the cloud computing infrastructure;** and **3) the decision-making component.**

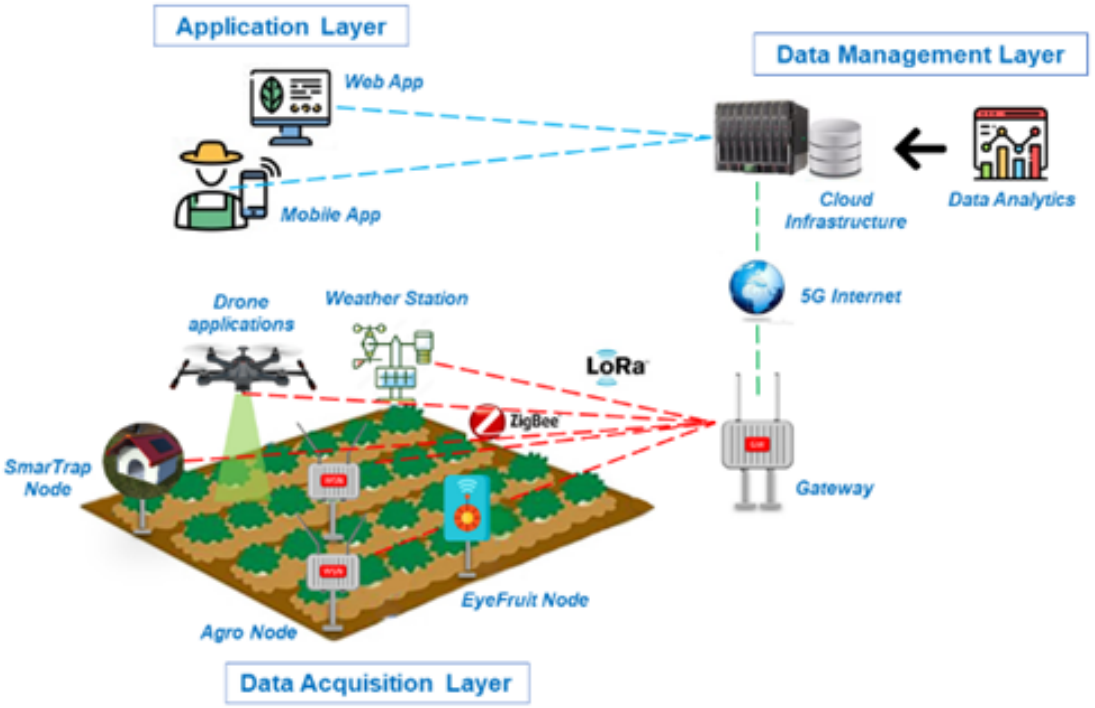

Fig. 1 - AgroNIT's architecture

4.i. The edge system

The edge system features a Wireless Sensor Network infrastructure equipped with various field-based electronic sensing devices-modules (e.g., capacitive soil water potential sensor, temperature sensor, precipitation sensor etc.), microcontrollers and Wireless Transceiver Devices to allow the monitoring, recording, and transmission of sensed data -over the internet- to the cloud for further analysis. The WSN-Wireless Sensor Network consists of solar-powered, autonomous devices (nodes) that are composed of the aforementioned modules which are open-source and reconfigurable. They are based on a modular architecture that allows flexible soft/hardware upgrades to feature various sensing modules. The devices also host different communication technologies (ZigBee, LoRa Wi-Fi, 4G-LTE). Those features allow the formation of different and of variable range wireless networks so that the sensing measurements can be transmitted reliably and with accuracy to the remote cloud storage infrastructure.

PANGAEA R&D PC, E. Katsigra 1, PC 41335, T +30.2413025570 E: info@pan-gaea.gr W: pan-gaea.gr

The devices of a WSN include: the field-based sensors - nodes: (agro, camera and insect trap), the weather stations, and the gateway nodes. The agro and camera nodes are installed at crop level, while the weather station together with the gateway node are located at the edge of a field.

The existing agro node is equipped with medium-cost, accurate crop, soil and environmental sensors that allow the monitoring of the most important parameters affecting crop development (air temperature/humidity, soil temperature/water potential, leaf wetness etc)

The existing camera node is installed at the crop level to monitor one (or more) fruit's development rate on a regular basis (a few times per day), by using a Raspberry Pi Camera Module V2 (8MP,1080p) camera sensor to obtain field-based images of the targeted fruit(s). Computer Vision solutions combined with AI algorithms can achieve significant results in the detection of patterns in images, such as fruit size and fruit color development in time. This pattern recognition can be interpreted to accurately estimate the fruit development degree and rate, contributing to optimized harvesting.

The existing weather stations, similarly to the agro nodes, are equipped with low-cost but accurate sensors that measure key climatic parameters, such as wind speed/direction, precipitation, and total solar radiation etc.

The SmarTrap are custom-made nodes to host a fully autonomous monitoring system of selectively collected insects. The monitoring system features a Raspberry Pi Camera Module V2 (8MP,1080p) camera sensor to capture images of the targeted sticky card placed at the bottom of the trap. The system is capable of capturing multiple photos and sorting them based on their definition, on a daily basis. The captured photographs are sent directly to the Cloud, via the node's communication system using 5G.

The existing gateway nodes provide the backbone network/ backhaul and support the remote configuration of each sensing device. They function as sensed data sinks, which are transmitted over the GSM/LTE network to the proprietary cloud platform, in real time.

4.ii. The cloud computing infrastructure

The proprietary cloud infrastructure comprises high-tech servers with high processing power and storage capacity. The cloud has multiple functionalities, since it

1. ensures the obtained data safe storage and offers a 24/7 data availability,
2. enables data analysis by integrated A.I. algorithms employing big data analysis and data mining methods,
3. incorporates tailor-made decision-making tools to generate appropriate advisory on the main cultivation practices, such as irrigation, fertilization, crop protection, harvesting, pruning etc., and
4. supports Web and mobile application functionality by employing modern graphics libraries.

4.iii the decision-making component

The AgroNIT software app, designed and developed for Web and mobile applications, integrates a plethora of custom-made services aiming to provide the user with a variety of capabilities, in a direct and friendly way. All the developed services are built to meet the

PANGAEA R&D PC, E. Katsigra 1, PC 41335, T +30.2413025570 E: info@pan-gaea.gr W: pan-gaea.gr

expectations of various potential users, such as farmers, agriculturists or policy makers, and cover a wide spectrum of the primary production. They can be distinguished in 7 categories:

1. Display service of field/crop/farmer basic information, such as the properties of the soil, the crop, the irrigation system, the farm equipment/machinery etc.
2. Display service of all field-based sensed data and images captured by the WSN, in real time. The acquired data are mainly presented using configurable graphs to facilitate end-user's access and interpretation.
3. Data analytics service aiming to interpret appropriately and extract useful conclusions for the end-user in the form of advice or notifications. it incorporates custom-made A.I. algorithms for 1) the estimation of real crop needs in water (irrigation) and nutrients (fertilization); 2) the assessment of the current crop's phenological status, by monitoring the accumulated chilling hours/portions and growing degree hours; as well as 3) to forecast potential threats from biotic and abiotic factors, such as diseases, pests or adverse weather phenomena, by monitoring local climatic conditions or weather forecasting, respectively.
4. Consulting/alerting service for the timely and accurate execution of the most important cultivation practices aiming to enhance resource efficiency in a sustainable way.
5. 48-hour weather forecast service integrating recommendations on the appropriate farmer's task scheduling based on the forecast.
6. Cultivation calendar service that incorporates a logger for task record-keeping by the farmer or the supervising agriculturist. The information provided can be used for better task planning as well as feedback to the advice provided by the system.
7. Auxiliary services encompassing the monitoring and record of crop's health status employing non-destructive methods and tools; such methods are remote sensing by UAVs equipped with RGB or multispectral cameras; the determination of a fruit's maturity using the DA meter, a handheld device that measures its chlorophyll content etc.

The flow diagram can be seen in Fig. 2. The predictive analytics are executed every time a field measurement is received, and the results are presented to the user on-demand when he/she makes a request or provides feedback or input through the app. Based on the received feedback, the data analysis tools can be configured accordingly to meet user's demands, while the available knowledge database will be continuously updated. The data analysis tools can produce early warnings and recommendations, as well as tailor-made reports, according to the user's input.

PANGAEA R&D PC, E. Katsigra 1, PC 41335, T +30.2413025570 E: info@pan-gaea.gr W: pan-gaea.gr

Fig. 2. AgroNIT flow diagram

It is worth to note that the AgroNIT can be used for the informed decision-making of its end-users in a direct, comprehensible and tailor-made way to enable the timely and accurate execution of their everyday tasks. More importantly, it constitutes a state-of-the-art, fully customisable, modular tool suitable for any public or private body active in the primary and secondary production sectors, in a wide spectrum of areas, such as Pomology, Large-scale Intensive Farming, Agrometeorology, Stored Products, Greenhouse Horticulture, Animal Production, Aquaculture etc.

4.iv Innovation step: Merging NordiCube to AgroNIT

The existing AgrNIT edge system (namely agro-nodes, camera-node, insect trap-node and the weather stations) could be further **optimized** taking the advantages of the **NordiCube** devices, minimizing simultaneously the associated **cost** of each agro-node and simplifying the hardware configuration, therefore the need for the existence of **alternative technologies** under the same box is eliminated. Furthermore, the overall **energy efficiency** could be increased by utilizing **specific mobile IoT technologies i.e. LT-M, NB-IoT.** Today AgroNIT is using AI/ML algorithms via the dedicated AgroNIT cloud platform, by transmitting sensor data to the cloud, resulting mostly in unnecessary power consumption.

However, the **integration of the proposed NordiCube module** to the edge system of AgroNIT while taking the advantages of It's embedded capabilities, such as the **low power nRF9160** chip and the companion **low power nRF5340** and ***nRF7002*** chips (for local mesh networking and commissioning), results in both the utilization of embedded AI/ML and SDK capabilities/algorithms towards to minimization of the bulk data transfer need to the cloud as well as the minimization of energy needs from the edge nodes up to the cloud.

Therefore, part of the existing (AgroNIT cloud based) AI algorithms could be replaced by the Edge Impulse embedded ML libraries, as they are embedded in the **nRF Connect SDK.** There is an opportunity here to test AI and ML tools on the Edge, in order to reduce the energy footprint of the IoT nodes, as well as of the system itself.

It is worth mentioning that by replacing existing nodes with **NordiCube** (hardware/firmware) could be **extensively deployed** as a real **IoT edge device** on the field, increasing the resolution of the IoT land spots and undoubtedly resulting in better accuracy and optimized efficiency of the Smart Farming IoT Ecosystem.

NordiCube (as a sensing-node part of AgroNIT Ecosystem) is also going to play an important role to the soils/waters monitoring all over flooded areas of Thessaly Region (especially after the catastrophic flash floods of September 2023).

More specifically, all over the land areas that covered of water and mud; especially the areas where the water level exceeded 2-4 meters, i.e. lake Karla tripled its original size, just in few days, extending lakeshores and waterbanks over a great number of villages and productive land field areas). Therefore, it is necessary to monitor -for long periods- the water/mud levels, as well as the soil parameters itself (moisture, water potential, temperature, salinity, Ph, nitrate content etc) in order to provide soil information to farmers, scientist and engineers towards land restoration. However, the restoration of the land areas that became inadequate for cultivation, is inevitably a long lasting and costly process.

PANGAEA R&D PC, E. Katsigra 1, PC 41335, T +30.2413025570 E: info@pan-gaea.gr W: pan-gaea.gr

5. NordiCube and UN Sustainable Development Goals - SDG

The proposed **NordiCube** module contribute mostly to the United Nations Sustainable Development Goals (SD**G 7:** Affordable and clean energy, **SDG 11:** Sustainable Cities and Communities, **SDG 13:** Climate Action and **SDG 15:** Life on Land), as follows:

- SMART AGRICULTURE / FARMING (SDG 11, SDG 13, SDG 15)
  Impact:

- **Optimized crop planning** and **resource management**, based on WSNs and IoT,
- **Optimized irrigation** allows for the more precision and adaptive cultivation protocols tailored to the individual crop needs

- WEATHER STATIONS (SDG 15)

  The weather station nodes are essential hardware for the AgroNIT smart Farming Platform and play a central role in our design monitoring/reporting the **local pedoclimatic conditions**, by measuring:
  Rainfall, Wind speed-gust and direction,
  Solar irradiance, Ambient light, UV, Temperature, Humidity, Barometric pressure, PM2.5 & PM10-(fine dust)

  impact:
- **Consideration for local pedoclimatic conditions**.
- Monitoring 247 the real conditions of the cultivation/environment.

- **Minimization of water input** by an efficient/optimized irrigation planning utilizing Smart Irrigation Decision Support System (SIDSS) that is composed of three components: a sensing device, a weather station, and a decision-making component.

- Networks of weather stations and sensors assessing crops' water requirements and soil properties enable continuous and real-time remote monitoring to assess the water status and flow through the entire continuum of soil, plant, and atmosphere.

- Adaptive water control: The Wireless Sensor Network - based monitoring edge system, feeds with its data the specific **simulation models / cultivation**

PANGAEA R&D PC, E. Katsigra 1, PC 41335, T +30.2413025570 E: info@pan-gaea.gr W: pan-gaea.gr

algorithms, the results of which can orchestrate the operation of an adaptive controller for the most efficient irrigation planning

- Applicability of Precise Sustainable Irrigation (PSI). PSI is a real-time decision-making process that combines field variability with other plant-related parameters, and rainfall forecasts to increase water use efficiency and food production while lowering the energy and labor costs associated with irrigation. PSI requires intensive real-time in-field data acquisition obtained by Wireless Sensor Networks (WSN),

- SURVEILLANCE - EARLY WARNINGS (SDG 15)

  The surveillance nodes are supplementary hardware of AgroNIT Ecosystem towards building a reliable early warning sensors based system.
  Monitoring various parameters: water leveling and water flows, Smoke and IR, soil water content, etc.
  Reporting flash floods / wildfires / heat and cold waves in combination with weather and weather stations data.

  IMPACT

  They are going to play an important role to the soils/waters monitoring all over flooded areas of Thessaly Region (especially after the catastrophic flash floods of September 2023).

  They are going to support the guard of the wild forest against the wildfires as an in situ early warning system for wildfires all over Greece (especially after the catastrophic wildfires in Volos and Alexandroupoli of August-September 2023).

  Could be also an ideal complementary system to different early warning systems that use remote sensing and various predictive models i.e. **DISARM Early Warning System for Wildfires in the Eastern Mediterranean,** see https://www.mdpi.com/2071-1050/12/16/6670

- SMART BUILDINGS (SDG 11, SDG 13)
  impact:

The internet of things (IoT) is changing the way people interact with their surroundings. In order to maximize opportunities, systems need to be connected and people need to be empowered with the right tools at the right time.

IMPACT

PANGAEA R&D PC, E. Katsigra 1, PC 41335, T +30.2413025570 E: info@pan-gaea.gr W: pan-gaea.gr

- Connecting people and spaces to deliver a seamless experience within smart built environments.
- With automated systems controlling various building systems, energy consumption can be reduced by up to 20%.
- This not only saves money but also helps the environment by reducing carbon emissions.
- Another major benefit is improved occupant comfort and convenience.

6. Conclusions

Among Pangaea R&D goals are definitely the development and the implementation of technological innovations and know-how, in the modern rural and urban areas, through collaborations with NITLAB https://nitlab.inf.uth.gr/, the utilization of the SLICES-RI https://www.slices-ri.eu/ (a flexible platform designed to support large-scale, experimental research focused on networking protocols, radio technologies, services, data collection, parallel and distributed computing and in particular cloud and edge-based computing architectures and services) via collaborative actions of complementary disciplines, thus covering the fields of **smart agriculture**, **smart cities**, **maritime informatics**, **telematics** and **innovative production technologies**.

Pangaea R&D (https://pan-gaea.gr) vision is a modern multidisciplinary approach towards the development of intelligent and environmentally friendly solutions in accordance with the current state of the art developments of the nRF91xx family chip of Nordic Semiconductors, realized via an add-on module, the **NordiCube**.

Pangaea R&D considers the **NordiCube** module as the first step towards Nordicsemi technologies exploration. By being confident that more and more technology advancements are coming in the future from Nordicsemi and its associates.

Our vision is to embed the new features/capabilities of **nRF9160** (Nordic Semiconductors) as a compact **low power SiP** with integrated LTE-M/NB-IoT modem and GNSS, with advanced processing and security capabilities, accessible and easy to use to a single device low power cellular IoT design, via **NordiCube** module, thus accelerating the time to market of our IoT products.

The above realizations of a series of state-of-the-art final products, along with the support of the engineering team of Nordicsemi, will guide us and our clients worldwide, to the path towards the achievement of the United Nations Sustainable Development Goals.

Pangaea's NordiCube module can be utilized by any 'Connect for All' participant. In this contest, since hardware is inline with nRF9160 DK, in fact we are envisioning to port and test any (competitors) software by using the NordiCube module. We strongly believe our modular concept NordiCube + M10CUBE I/Os (with NordicPico on board) can be benefited by any bright idea .

PANGAEA R&D PC, E. Katsigra 1, PC 41335, T +30.2413025570 E: info@pan-gaea.gr W: pan-gaea.gr

Appendix

I. ‘AgroNIT: Innovating Precision Agriculture’, 2022 Global Information Infrastructure and Networking Symposium (GIIS)

Ioannis Moutsinas†,‡, Antonis Kalkanof†, John Mavridis†, Vassilis Zafeiris†, Foteini Oikonomou†, Georgios Tziokas†, Kostas Themelis†, Katerina Kyriakou†, Christos Theologou†, Argyris Serafeim†, Apostolos Apostolaras†, Persefoni Maletsika‡, George D. Nanos‡ and Thanasis Korakis†
†Department of Electrical and Computer Engineering, University of Thessaly
‡Laboratory of Pomology, School of Agricultural Sciences, University of Thessaly

II. ‘NordiCube©2023’ project presentation