# SUPERIOT project

## Newsletter #1

## *July 2023*

- *Overview of the activities planned at VTT in SUPERIOT*
- *Wavecom develops ideas on the potential applications*
- *University of Oulu presents the initial RIoT designs*

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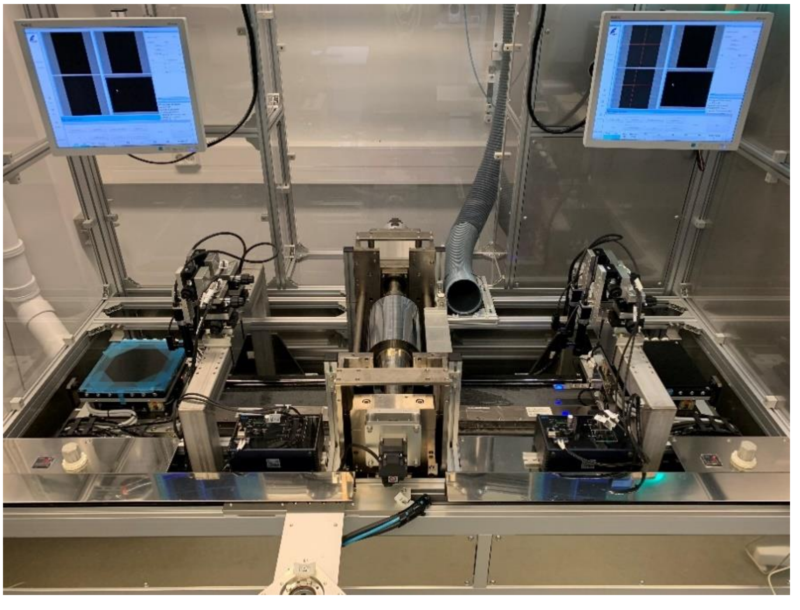
# VTT plans for SUPERIOT

The Technical Research Centre of Finland Ltd. (VTT) brings to the SUPERIOT project its expertise on the development of printed components with sustainable manufacturing and materials, integration of functional printed electronic devices, and environmental impact analysis.

VTT will develop circuits for IoT nodes based on high resolution reverse offset printing (ROP) that can offer linewidths and overlay accuracy to a few microns, thus suitable for the fabrication of multi-layer thin-film devices. SUPERIOT will build on VTT's print-patterned metal oxide thin-film transistor (TFT) process [see for example Fei Liu *et al.* Flex. Print. Electron. **8** 015017 (2023)] and target improving the fabrication yields to allow complex circuits. Such miniaturized TFT devices are needed for maximizing the use of printing-based fabrication in IoT nodes through circuits that can reach relevant operation frequencies.



*Reverse offset printing (ROP) printing and flexible OPV cells.*

VTT will also develop energy harvesting for reconfigurable internet of things (RIoT) optical-radio concept nodes. In SUPERIOT, thin and lightweight organic photovoltaic (OPV) structures will be optimised (*e.g.* for environmental conditions, lighting levels *etc.*) to be applicable for the use case demonstrations. OPV aims for low environmental impact materials and avoids the use of critical raw materials, hazardous substances and materials associated with high $CO_2$ emissions or high energy consumption. Furthermore, manufacturing will be based on up-scalable, energy and material efficient processing technologies, namely printing and coating.

For integration of some of the SUPERIOT demonstrators, VTT will use its world-class facilities for printed functional solutions. VTT possesses a unique roll-to-roll (R2R) pilot manufacturing environment for Printed Intelligence processes enabling development and manufacturing of demonstrators and prototypes up to industrial scale consisting of pilot printing machines (30 cm roll width), post-treatment line, chip assembly machines, and laser processing facilities, as well as tabletop printing machinery.

Life cycle assessment (LCA) is a method for quantitatively and systematically evaluating the potential direct and indirect environmental impacts of a product or system throughout its whole life cycle. VTT has provided sustainability and LCA expertise since 1990, and during recent years, has been involved in several assessments of electronics (*e.g.* Välimäki et al. 2020). In SUPERIOT, LCAs will be carried out for the project demonstrators to guide the development process towards decreased environmental impacts, and to analyse the impact of the integrated demonstrators.

### Related work at VTT

VTT has established experience in developing sustainable electronic solutions. In the national ecosystem project ECOtronics (www.ecotronics.fi) VTT and partners analysed what are the main factors affecting the environmental impact of electronics and investigated what is technically feasible in solving the challenges. The work will continue in the soon-to-be-started KDT JU Sustronics project. In the CHIST-ERA funded research project TESLA (*Transient Electronics for Sustainable ICT in DigitaL Agriculture;* www.teslaresearchproject.eu), VTT will develop biodegradable and transient OPV modules for precision agriculture. In a similar application field, in the Academy of Finland-funded SOIL project, materials that are plant-based or act as plant-nutrients are utilised in high resolution ROP to develop biodegradable electronic circuits. The EC-funded Graphene Flagship (www.graphene-flagship.eu) aims to develop complete solutions from 2D materials, and graphene in particular, that are simultaneously more sustainable and higher performance than current technology in areas such as wearables, (bio-)sensors and microelectronics, as well as non-electronic applications such as composites and water filtering.

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This VTT project portfolio will support SUPERIOT's vision for maximising the use of printed electronics and enable sustainable manufacturing of future IoT nodes.

## SUPERIOT applications

wavecom

Over the last period, Wavecom was has been working closely with the other project partners to develop ideas on relevant scenarios and applications in which SUPERIOT technology could be relevant, and to identify the specific (quantified) requirements. During this process, three main scenarios were defined, namely:

**Smart tags and labels** Future smart tags and labels for identification and traceability of objects (static or moving) and people, with enhanced functionality when compared with barcodes, QR codes or even RFID (radio frequency identification) labels.

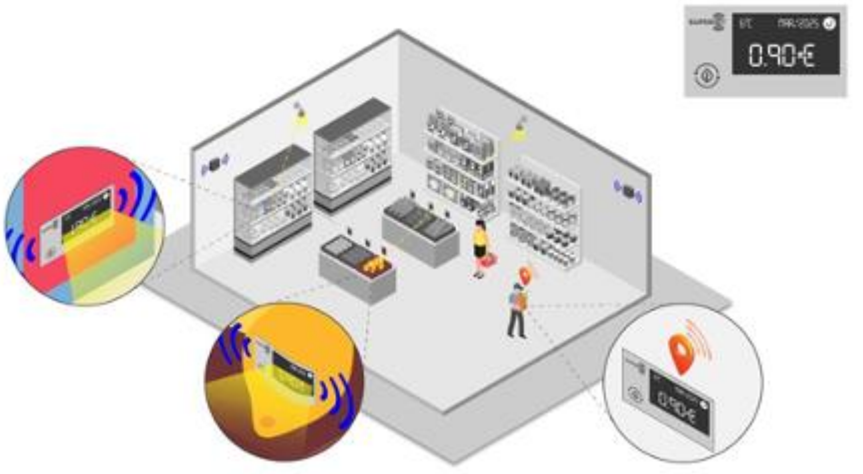
**Large-scale sensing and actuation** Sustainable and inexpensive devices that can be deployed on a large scale for environmental sensing and actuation. These devices communicate relevant parameters to the network and are also able to act in the environment.

**Enhanced IoT communication in demanding environments** Technology developments that may be used to improve many types of applications. This scenario serves as a future technology platform to enhance IoT communication capabilities in general.

For each scenario, several different application examples were described and some illustrative examples were created.

### Smart tags and labels

This schematic (right) depicts examples of sustainable smart tags and labels used on day-to-day market products. These labels could monitor the location and quality of products in real-time, and dynamically communicate the relevant data over light and radio. An incorporated display could be used to give information about expiry dates, temperature, *etc.*

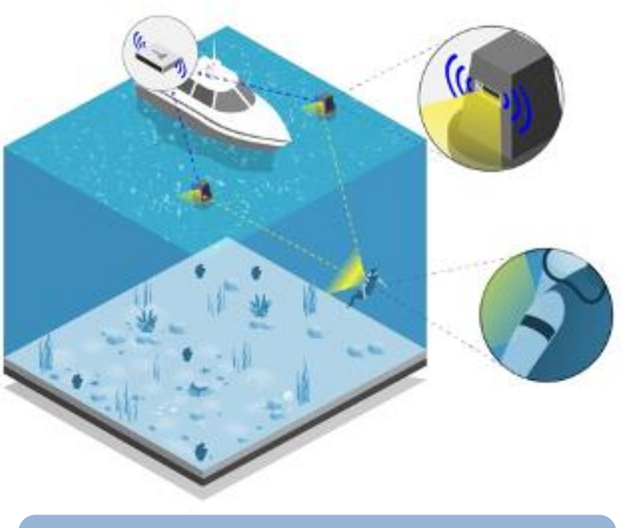



### Large-scale sensing and actuation in forestry

In this application (left), trees are being monitored with the eco-friendly SUPERIOT nodes. The actuation capabilities of nodes could help to nurture and protect plants and trees by intelligently releasing fertilizers, drugs against plant diseases, or even fragrances to attract/repel insects.

### Enhanced IoT communication in demanding environments

In underwater situations, where radio communication is challenging, IoT nodes on the surface could provide connectivity by using light below the surface (diver), and radio above (boat). Printed electronics would help create nodes that are autonomous, environmentally friendly, and can be easily adapted to a submarine environment.



Wavecom will continue to refine the applications and use cases to be demonstrated in the project, including the gathering of requirements, helping to steer the development of SUPERIOT.

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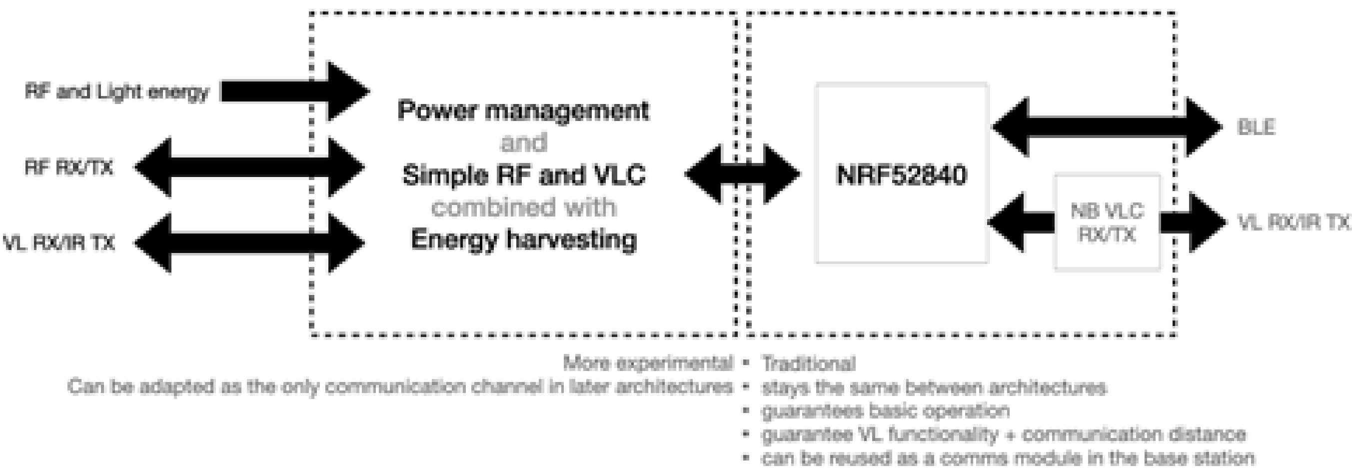
# Sustainable RIoT node design

UNIVERSITY OF OULU

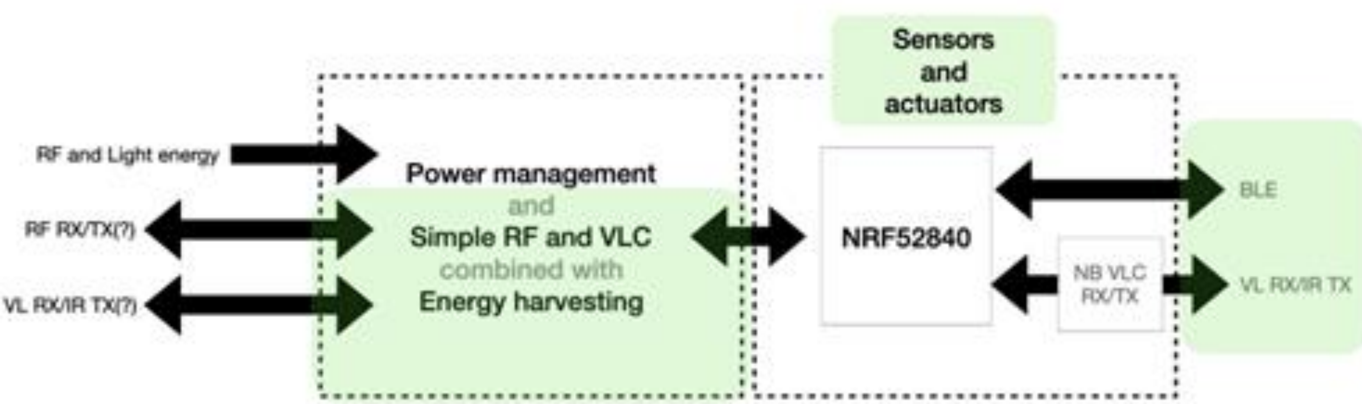
## Node architectures

One of the University of Oulu's main tasks in the first six months of the project has been to lead the task on reconfigurable IoT (RIoT) node architecture. This includes the development of the hardware implementation of the RIoT node. UOULU work at the architectural level of the RIoT node has led to three architecture proposals, namely the:

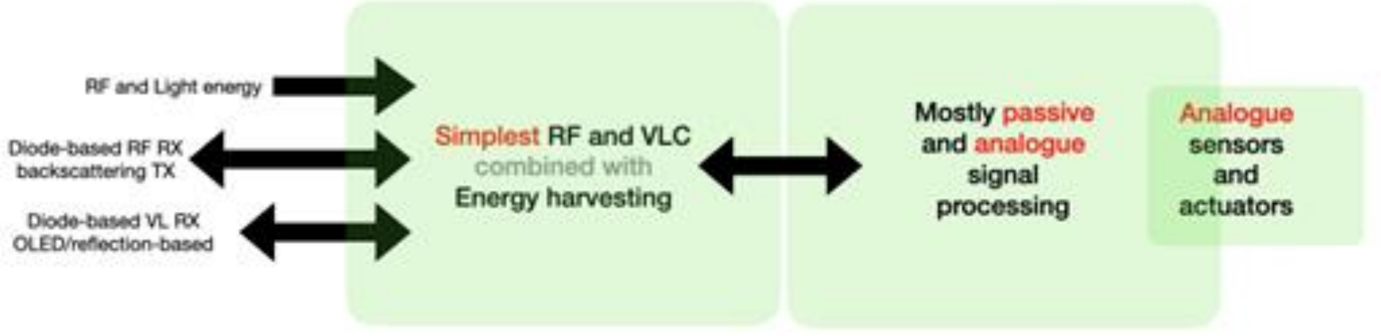
Reference node which will serve as the benchmark for other node designs and will be built using conventional Si-based components and manufacturing methods.




Hybrid node which is the primary node developed in the SUPERIOT project, manufactured using both traditional and printed components, such as organic photovoltaics (OPVs), super capacitors and antennas.



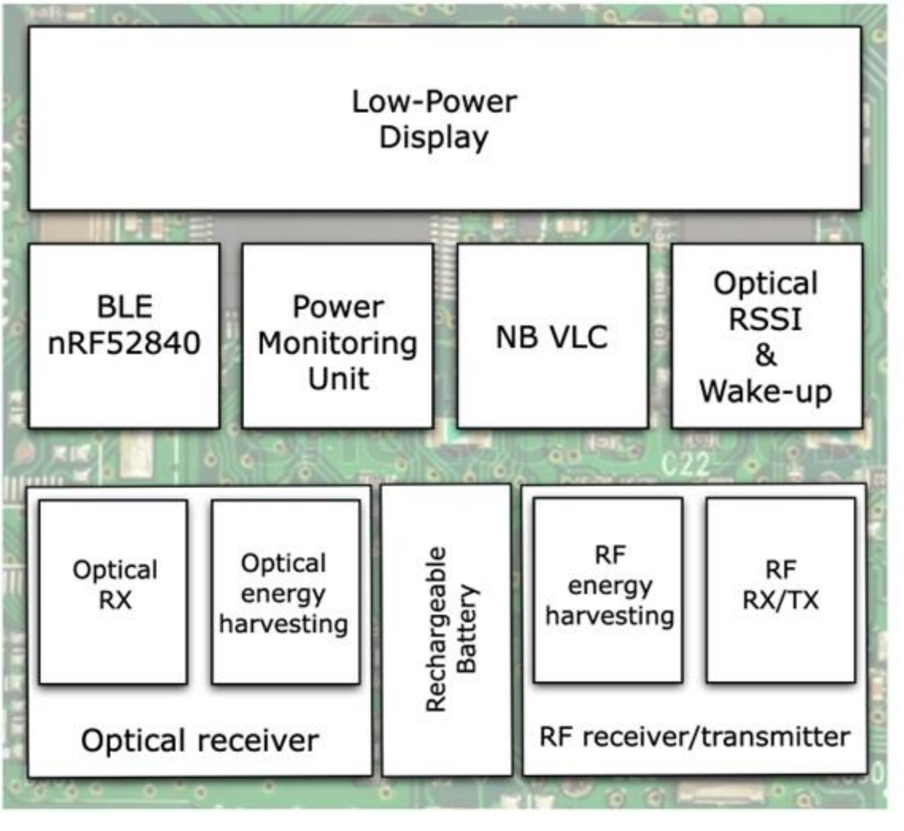
All-printed node which is the most challenging experimental design and represents the first attempt to make a complete IoT node using only printed components.




## Reference node hardware architecture

The actual hardware architecture under development of the first node type (reference node) is shown opposite. The architecture is built around the nRF52840 BLE (Bluetooth low energy) enabled micro-controller from Nordic Semiconductor. Novel light (*i.e.* narrow-band visible-light communication) and backscattering-based RF communication channels augment the Bluetooth communication and positioning provided by the nRF52 SoC.

The architecture includes a multi-channel power monitoring unit for power estimation and modelling, optical received power measurement and wake-up circuit, and RF and optical power harvesting circuitry.




*A schematic of the reference node architecture.*

*BLE nRF52840: Bluetooth low energy enabled micro-controller from Nordic Semiconductor*

*NB VLC: Narrow-band visible light communication*

*RSSI: Received signal strength indicator*

*RX: Receiver*

*TX: Transmitter*

*RF: Radio frequency.*

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