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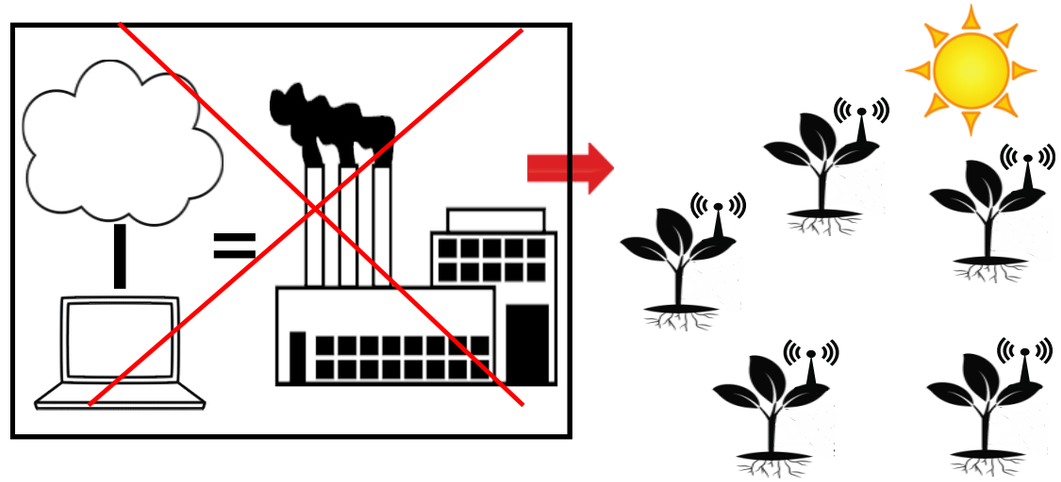
Description of the funded research project

1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and Procure High-Value Research Equipment



Title of the research project:
Batteryless, Ambiently-Powered Internet of Things That Think: An Asynchronous Message Passing Approach (AMPERE)

Principal Investigator: **Prof. Aggelos Bletsas**

Reader-friendly title: **Batteryless IoT that think!**

Scientific Area: **ENGINEERING SCIENCES & TECHNOLOGY**

Institution and Country: **Technical University of Crete (TUC), Greece**

Host Institution: **Telecommunication Systems Institute of Technical Univ. of Crete (TUC), Greece**

Budget: **187887 Euro**

Collaborating Institution(s): Electrical and Computer Engineering (ECE) Department, University of Virginia, USA

Duration: **36 months**

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Research Project Synopsis

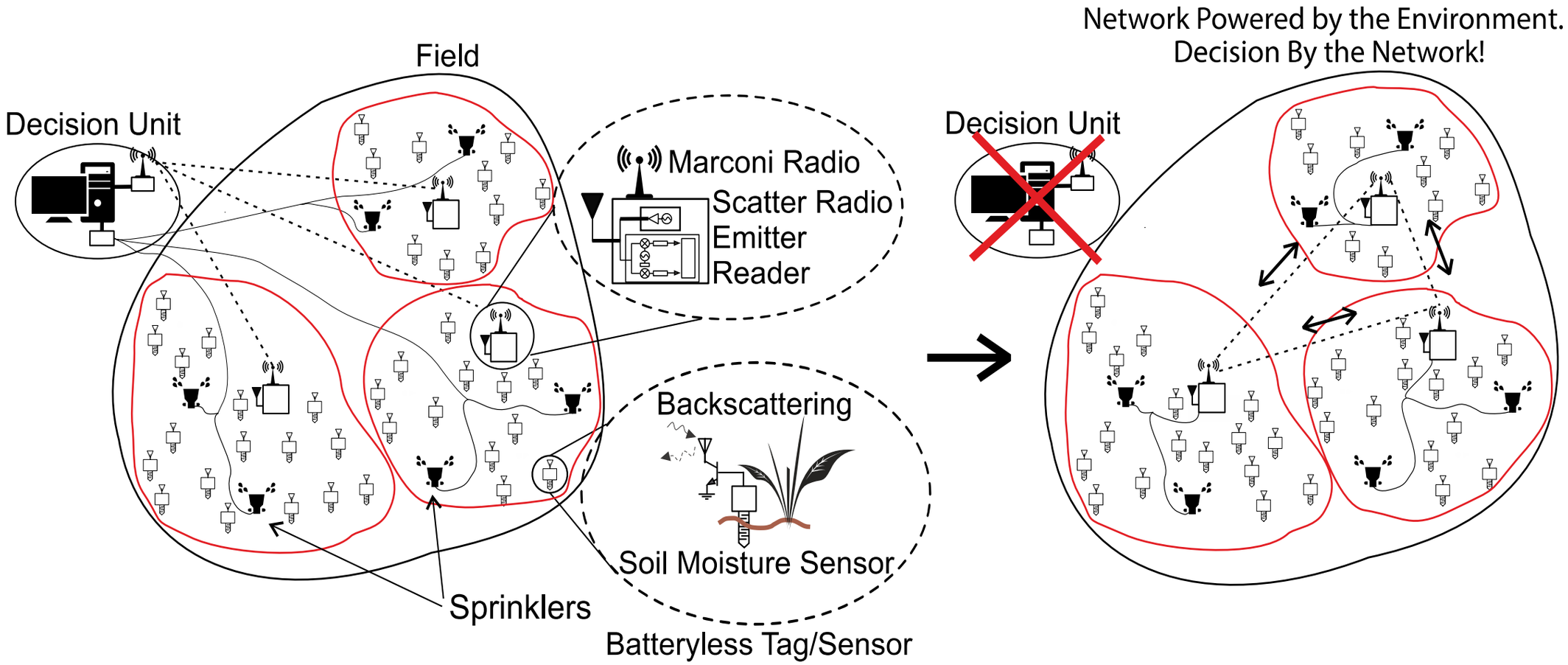
Powerful message passing algorithms (e.g., sum-product, max-product) have offered concrete examples on how decision making and inference can be facilitated through communication, at carefully crafted probabilistic graphs. More importantly, recent advances on scatter radio sensor networks by the PI have demonstrated feasibility of ultra-low power (in the order of 20 microWatts) and cost (in the order of some Euros), joint sensing and wireless networking, through single-transistor radio frequency (RF) front-ends and reflection radio principles. Furthermore, the PI has demonstrated energy harvesting circuits from ambient RF or bioelectric sources (plants) with record-breaking sensitivity, able to harvest ambient power, as small as 1 microWatt.

AMPERE is inspired by the fact that ambient energy, e.g., solar, kinetic, thermal, bioelectric or RF, has a common characteristic: fixed (on average) density per squared (or cubic) centimetre and thus, wireless sensor networks (WSN) over an extended area (or volume) could in principle harvest a large amount of energy. Thus, autonomous, in-network decisions should be possible, solely using ambient power,
1) by exploiting ultra-low power wireless communication principles (e.g., scatter radio) and novel energy harvesting circuits, and more importantly,
2) by balancing the WSN computation and communication load of (inherently parallel and distributed) asynchronous message passing algorithms (for inference), across various (distributed in space) WSN nodes.

AMPERE offers a methodology framework for reliable inference from unreliable, ambiently-powered WSNs, with bounded execution time, quantified convergence/correctness tradeoffs, careful modifications of message passing for efficient communication, exploitation of powerful asynchronous message passing algorithms (e.g., for clustering, signal de-noising/reconstruction), as well as hidden links between message passing algorithms and iterative numerical methods. Case studies in environmental sensing / agriculture and home automation will be examined with tremendous socioeconomic impact, while the design principles should accommodate other applications.

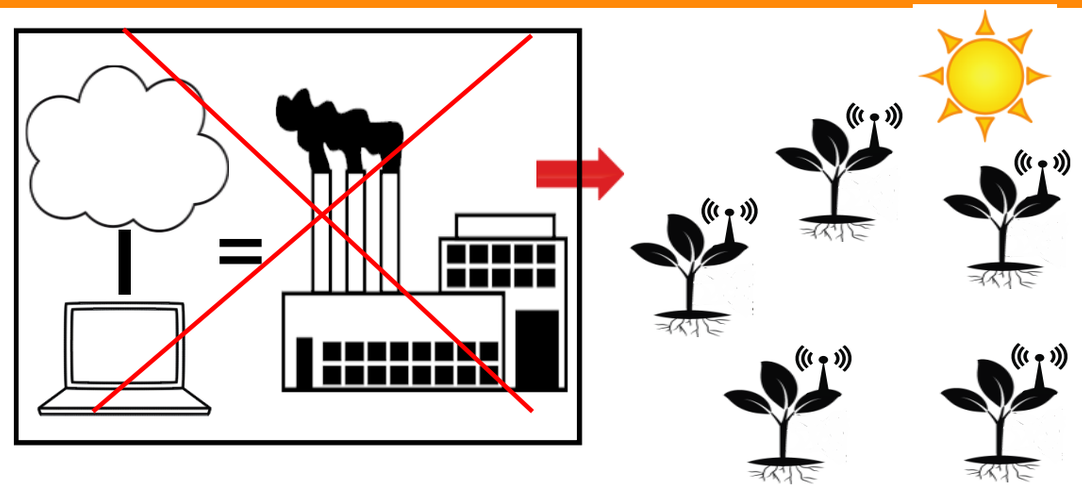
AMPERE attempts a concrete step from coming Internet-of-Things to future Internet-of-Things-that-Think with ambient energy.

Project originality



- **Offer design principles of wireless sensor networks (WSN) that autonomously, in-network infer about the problem at hand, based on the sensed information, using asynchronous message passing algorithms and no central processing or cloud service;**
- **Exploit PI's recent findings on micro-energy harvesting, including RF and bioelectric sources and offer design principles for WSNs solely powered by ambient sources (e.g., solar, kinetic, thermal, bioelectric or RF), with quality-of-service (QoS) guarantees and realistic models of ambient energy harvesting;**
- **Showcase the discovered principles with tremendous socioeconomic impact applications (e.g., in environmental sensing/agriculture, home automation);**
- **Progress from coming Internet-of-Things to future *Internet-of-Things-that-Think* with ambient energy.**

Expected results & Research Project Impact



- ***AMPERE does not only focus on packet exchange from ambiently-powered nodes but also facilitates distributed, in-network processing, i.e., network inference on the collected data: "Things that Think".***

- ***AMPERE exploits ambient micro-energy distributed in space, by also simplifying and distributing the required computation over space, using the inherently parallelizable framework of inference and belief propagation/message passing algorithms.***

- ***AMPERE performs embedding of the inference/message passing algorithm into the wireless sensor network, carefully designing the tradeoff between execution delay and quality of the final solution.***

- ***In sharp contrast to prior art, asynchronous operation of message passing is turned to an advantage.***

- ***AMPERE models the physics of ambient energy availability based on "hands-on", working knowledge of the PI on harvesting circuitry non-idealities, such as limited sensitivity, nonlinearity and conversion delay.***

- ***AMPERE offers concrete working demonstrations, relevant to agriculture and home automation.***

The importance of this funding

- ***H.F.R.I. funding assists in supporting high-quality junior researchers (e.g., MSc students and PhD candidates), who otherwise would have left abroad…***
- ***H.F.R.I. supports basic (but competitive) research…***

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COMMUNICATION

185 Syggrou Ave. & 2 Sardeon St. 2
171 21, N. Smyrni, Greece
+30 210 64 12 410, 420
communication@elidek.gr
www.elidek.gr