Innovative & Intelligent Internet of Things
Research Needs: Innovative and Intelligent Internet of Things
July 2016

The Semiconductor Research Corporation (SRC) Global Research Collaboration (GRC) program member companies are pleased to release this document that describes the research needs in the Innovative & Intelligent Internet of Things. Incorporated into this document are the needs identified through SRC GRC Executive Technical Advisory Board (ETAB) priorities, the Innovative & Intelligent Internet of Things (I3T) TAB strategic planning process and other discussions.

The I3T research needs of the members should address and develop breakthrough technologies enabling the next generation of intelligent, connected, and autonomous devices in the following five categories:

- Energy constrained connectivity and computation
- Ultra-low power sensing and actuation
- Autonomous energy sources and management
- Security in devices and communications
- Integration and packaging

Each of these major categories are broken down into several sub-categories which describe the need in more detail. Even so, these are written to be broad in nature to not restrict the investigator's approach.

This needs document is driving the Innovative & Intelligent Internet of Things solicitation. It is issued to universities worldwide, may be addressed by an individual investigator or a research team. Our selection process is divided into two stages. The interested party is requested to submit a brief 1-page white paper. The white paper should clearly identify what can be done in two years, as well as what additionally could be done if a third year is requested. (Please specify the third-year goals separately.) Two-year-only white papers are also acceptable. A successfully selected white paper will result in an invitation to submit a full proposal, with recommendation that the proposal will be written for 2 years or 3 years. These proposals will be further down-selected for research contracts. The number and size of the contracts awarded will be determined by the amount of available funds, and by the number of high-quality proposals

Investigators who are funded will be expected to publish at top-tier conferences, including but not limited to, IEEE World Forum on Internet of Things, IEEE Sensors Conference, International Conference on Solid-State Sensors, Actuators and Microsystems, Symposia on VLSI Technology and Circuits, CICC, ESSCIRC, ISSCC, and MOBiCOM.

White Papers for all the categories below will be considered for funding. Note that there is no priority assigned to the order of the major categories or the sub categories. Investigators are limited to participation in two white papers in this solicitation. Submissions should highlight major category needs are addressed, such as "I2".

CONTRIBUTORS

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2016 Innovative and Intelligent Internet of Things Needs Categories

I1	**Energy Constrained Connectivity and Computation**
Connectivity and computation is a broad category that includes: radio, network transmission, on-chip interconnect energy reduction (including techniques that enable energy efficient scaling of compute cores), techniques that enable faster transmission of state from one compute device to the next, as well as to the edge of network and back (software-hardware techniques considered), techniques that fuse sensor data to increase information density/value, and techniques that enable compute near data (also known as PIM, or in-memory computation) for energy constrained devices (as well as general purpose devices). This category also includes novel memory technologies, and techniques that improve efficiency of existing memory technologies.	
I1.1	Novel techniques to reduce on-chip fabric/interconnect/bus energy and improve efficiency of scaling within a system on chip (SoC)
I1.2	Techniques to schedule/partition computation and/or data based on some cost function, such as power/energy or communication overhead constraints.
I1.3	Techniques that enable near memory computation or processing in memory (memory coupled with logic) to reduce data movement (can include novel memory coupled to logic, novel techniques to integrate with existing memory technologies, etc.)
I1.4	Methods to reduce energy consumed by memory at the end node (includes novel storage, volatile, non-volatile memory, as well as novel techniques to enhance current memory technologies)
I1.5	Techniques to fuse/process multiple sensor data streams to provide higher information value as well as decrease energy/bandwidth usage
I2	**Ultra Low Power Sensing and Actuation**
Novel Si-based sensing and actuation technologies will be the key enablers for IoT applications in automotive, building automation, industrial automation, medical, and consumer electronics. To enable the deployment of large numbers of these sensors and actuators, power consumption, cost and security are the most challenging issues for IoT applications. One of the approaches to reduce the power consumption at the system level is to have more intelligence in sensors and/or multi-modality sensor fusion, such that decisions can be made with sensor data locally without sending unprocessed data to the cloud. This will also reduce actuator latency. Environmental, chemical, biochemical, audio, image, gesture, and motion sensing are of particular interest.	
I2.1	Intelligent sensing/data fusion: sensors combined with local, low power data processing to reduce data communication and to enable local decision making
I2.2	Compressive sensing techniques, such as those exploiting signal sparsity, which extract "useful" data from sensors
I2.3	Novel low power sensing and actuation principles and devices
I2.4	Ultra-low power data conversion, signal processing, actuators, drivers, and interfaces
I2.5	Compact device models for circuit simulation
I3	**Autonomous Energy Sources and Management**
Silicon and package integrated energy sources, storage, and management will be critical to enabling energy-independent IoT devices. The integrated ability to scavenge, store, and manage energy enables widespread deployment of autonomous sensor networks, and in-situ/harsh environment devices which cannot rely on conventional energy sources. To make energy autonomous devices practical, they should be able to harvest from multiple energy sources (e.g., solar, thermal, mechanical, electromagnetic), store energy with low-leakage for extended periods of times in devices such as batteries, super capacitors, and resonators, and use low-power energy management techniques to optimize harvesting and storage functionality.	
I3.1	Hybrid harvesting: management techniques for multiple energy-source harvesting and storage
I3.2	Integrated storage: silicon and package-based energy storage devices including thin-film batteries and super caps
I3.3	Integrated harvesting: silicon and package-based methods to harvest energy from a variety of sources such as mechanical, solar, electromagnetic, electrochemical, and thermal energy
I3.4	Ultra-low power compact energy management: low input voltage, low quiescent current chargers and boost converters

I4	**Security in Devices and Communications**
IoT involves interconnection of massive numbers of sensors, which collect and transmit physical world data, actuators, that control or stimulate systems in the physical world, and computation elements, which analyze the sensor data and/or control the actuators, and energy sources. There are already known examples of breaches of security of both wireless and wired sensors and actuators, so security of the IoT against malicious attacks is critical, for all elements, including sensors, actuators, computation, memory, interconnect, and energy sources. The security should involve minimum overhead, especially for wireless devices that use energy harvesting so they operate without an external power supply. Security is required to prevent unauthorized access to data from, and malicious control of, sensors and actuators, and to protect the integrity/authenticity/privacy of computation and data across the information hierarchy (e.g., app to cloud to gateway to edge).	
I4.1	Authentication for device-to-cloud and cloud-to-device transactions
I4.2	Device data and software program security
I4.3	Secure wireless and wireline network topology and communication protocols
I4.4	Low power secure communications techniques
I5	**Integration and Packaging**
Devices for the IoT often need to be small and cheap, and in some cases will need to operate in extreme environments, such as hot automobile engines, industrial facilities and building automation, home appliances, corrosive surroundings such as within the human body, dirty/natural areas such as an agricultural field, and may experience any combination of severe impacts, vibrations, galvanic corrosion, liquid immersion, and temperature extremes. IoT devices for wearable electronics, clothing, agriculture, etc. may also need to be flexible and have the ability to sustain high flex cycle counts. Integration and packaging of circuits, sensors, actuators, MEMs devices, antennas, power sources, etc. into the physical-world-facing sensor and actuator devices is therefore a critical aspect of the IoT. Basic packaging research on materials and interfaces, thermal and power management, and high bandwidth and connection count are covered under other GRC thrusts; submissions of interest for the I3T thrust should emphasize the areas noted above for edge devices.	
I5.1	Novel packaging and interconnect to achieve miniaturized form factors for edge devices
I5.2	Integration and testing of mixed technology systems (computation, RF, MEMs, bio-electronic, etc.), especially of self-powered edge devices
I5.3	Low cost packaging approaches for hostile environments
I5.4	Packaging and integration solutions for flexible/wearable devices