Guest Editors' Introduction: Intelligent Resource-Constrained Sensor Nodes

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Following continued system miniaturization for over past five decades, the size of unit computing has been steadily shrinking. In the foreseeable future, computing will be all around us, in mostly invisible forms, and is expected to lead more than 50 billion Internet-of-Things (IoT) devices, at the forefront of which will be distributed sensing nodes acting as the eyes and ears of IoT.

Significant progress in the transducer community has made it possible to sense a variety of parameters (e.g., images, video, audio, location, temperature, pressure, smell) in miniaturized sensor nodes. However, typically due the small form factors, such sensor nodes often face severe resource constraints (e.g., energy, size, latency, and connectivity bandwidth). Future intelligent systems require such sensor nodes to intelligently work under varying operating condition, to work with the network and cloud maximizing information transfer, and to work cooperatively among themselves to increase collaborative intelligence. There will be huge amounts of data (some estimates project upward of 30 exabytes per month in the world by the end of this decade) generated by such IoT sensor nodes leading to network congestion. Moreover, since unit communication energy cost is typically much higher compared to unit in-sensor computation energy cost, sending all the generated data to the cloud leads to low sensor battery lifetime. This calls for transforming from the "data domain" to "information domain" (using in-sensor analytics) as soon as possible in the data hierarchy. The sensors need to "learn" what to sense, when to sense, and at what resolution at an individual level and through collaboration among multiple sensors. The sensor nodes need to decide "on the fly" how much to send to the cloud to minimize the network traffic while maximizing the information transferred and network intelligence while simultaneously minimizing not only *energy/bit* but also *energy/information*.

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This special issue will cover recent advances of such context-aware, self-learning, intelligent sensor nodes for IoT enabled by advances focused *within the sensor nodes*, operating under severe resource constraints. Four articles focusing on vertically integrated IoT sensor node SoC design challenges are presented in this issue.

The first article "Context-Aware Intelligence in Resource-Constrained IoT Nodes: Opportunities and Challenges," provides an academic perspective of the problem. This article provides a survey of recent advances in the last decade in intelligent sensing, computation, communication, and energy-management focused toward a resource-constrained

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IoT sensor node and also gives an overview of the future outlook and needs.

The second article, "Edge Intelligence—On the Challenging Road to a Trillion Smart Connected IoT Devices," adds in industry and government perspective to the problem of intelligence in resource-constrained IoT nodes and presents a vision of the future and important technologies that might play a strong role in enabling the vision of trillion smart connected sensors.

The third article, which is a keynote paper, "The Internet of Tiny Things: Recent Advances of Millimeter-Scale Computing," presents a summary of the state-of-the-art advances in mm-scale computing focusing on the mm^3 platform.

The final article from Intel Labs, "Intelligent IoT Motes: Preventing Their Abuse at the Weakest Entry Point," presents security challenges for resource-constrained IoT devices. This article points out that, due to limited resource availability, IoT nodes could be the weakest security link in the massive IoT networks. The article also presents current best practices and future security needs for IoT devices. ■

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