DARPA's N-ZERO extends the lifetime of IoT devices and remote sensors from months to years

Today U.S. soldiers are being killed because the Defense Department cannot deploy all the sensors it would like to. DoD could deploy sensors every few yards to detect buried improvised explosive device (IED). As it is, every sensor deployed today has to be battery powered, so even if vast sensor nets were deployed it would put more soldiers in jeopardy by forcing them to expose themselves to ambush attacks while changing sensor batteries.

By 2018 the DARPA's N-Zero initiative aims to have deployable sensor networks that require near-zero standby-power, a goal the team quickly found that was impossible without microelectromechanical systems (MEMS). In addition the teams discovered an extra benefit of MEMS — an advantage the team had never imaged possible. MEMS provides not just near-zero standby power, but can be configured for absolute zero standby power by using the power from the signal to be detected itself to power-up the transmitter. And in some situations, the transmitter too can be powered without a battery, by storing up energy on a super-capacitor from renewable sources — from solar to vibration harvesters.

The Department of Defense has an unfilled need for persistent, event-driven sensing capabilities, where physical, electromagnetic and other sensors can remain dormant, with near zero-power consumption, until awakened by an external trigger or stimulus. Current state-of-the-art sensors use active electronics to monitor the environment for the external trigger, consuming power continuously and limiting the sensor lifetime to months or less.

The N-ZERO program intends to extend the lifetime of remotely deployed communications and environmental sensors from months to years, by supporting projects that demonstrate the ability to continuously and passively monitor the environment, waking an electronic circuit only upon the detection of a specific trigger signature. Specifically, N-ZERO seeks to extend unattended sensor lifetime from weeks to years, cut costs of maintenance and the need for redeployments. Alternatively, N-ZERO could also reduce battery size for a typical ground-based sensor by a factor of 20 or more while still keeping its current operational lifetime.

“We wanted to learn how to reduce our sensors power envelope so that we could deploy them right at the tactical edge with a battery that does not need to be replaced for a long period of time,” said DARPA program manager Roy (Troy) Olsson in his keynote address titled Event Driven Persistent Sensing.

A team of researchers at Northeastern University have developed a new sensor powered by the very infrared energy it’s designed to detect. The device, which was commissioned as part of DARPA’s Near Zero Power RF and Sensor Operation (N-ZERO) program, consumes zero standby power until it senses infrared (IR) wavelengths. The sensor shall have many military applications that can detect vehicles and tanks and even identify them weather it is a truck, a car, or an aircraft by detecting heat emitted by them in IR spectra and analysing the heat or IR signature which is different because of engines that burn gasoline or diesel fuels produce emissions made up of different chemical compounds.

Requirement of new technologies to power IoT and wireless sensor networks

DARPA’s N-ZERO program can also enable the future billions of

Internet of Things (IoT) devices that shall be deployed 'everywhere' and to be accessed 'any time' from 'anywhere'."What we can do today really doesn't fulfill the vision of the Internet of Things," Troy Olsson, DARPA's N-ZERO program manager, told SIGNAL. "We can either connect devices that have power already, like your refrigerator, or devices that you can recharge every day or every couple of days, like a cellular phone. You can connect and interconnect those, and some people call that the Internet of Things." For Olsson, true IoT will involve sensors everywhere that are untethered from either a power supply or from having to be recharged constantly

To power future billions of Internet of Things (IoT) shall require billions of batteries to be purchased, maintained, and disposed of. Energy harvesting presents the best alternative for large-scale self-contained IoT is ambient energy sources. State-of-the-art (SOA) sensors use active electronics to monitor the environment for the external trigger, consuming power continuously and limiting the sensor lifetime to durations of months or less. In addition, it increases the cost of deployment, either by necessitating the use of large, expensive batteries or by demanding frequent battery replacement. It also increases Warfighter exposure to danger. Researchers have evolved many approaches to tackle the energy consumption of battery powered devices. Wireless sensor network standards have been specifically designed to take into account the scarce resources of nodes.

Sensor devices are made up of sensing capabilities, communicating components and data processing. The sensor nodes gather information or detect special events and send the data to the base station to be processed. Radio module is the main component that causes battery depletion. To reduce energy dissipation due to wireless communications, researchers have tried to optimise radio parameters such as coding and modulation schemes, power transmission and antenna direction.

Another category of solutions aims to reduce the amount of data to be delivered to the sink. Two methods can be adopted jointly: the limitation of unneeded samples and the limitation of sensing tasks because both data transmission and acquisition are costly in terms of energy.

Idle states are major sources of energy consumption at the radio component. Sleep / wakeup schemes aim to adapt node activity to save energy by putting the radio in sleep mode.

DARPA seeks to transform the energy efficiency of these unattended sensors through elimination or substantial reduction of the standby power consumed by the sensors while they await a signature of interest. The improved energy efficiency is expected to result in an increase in the sensor mission lifetime from months to years.

DARPA's N-ZERO program

The program intends to exploit the energy in the signal signature itself to detect and discriminate the events of interest while rejecting noise and interference. N-ZERO program intends to develop the underlying technologies and demonstrate the capability to continuously and passively monitor the environment, and wake-up an electronic circuit upon detection of a specific trigger signature. Thus, sensor lifetime will be limited only by processing and transmission of confirmed events, or ultimately by the battery self-discharge.

The N-ZERO program has three phases. The first, which ended December 2016, took 15 months to complete. The second and third phases will each take one year. Some research teams achieved goals in the program's first phase that they were expected to reach much later.

Ultimately, the goal of the N-ZERO program is to design, build, and test intelligent sensors and microsystems that exploit the energy in, and the unique features of, a signature of interest to process and detect the signature's presence, reject noise and interference, while consuming less than 10 nW. The goal is to use less than 10 nanowatts (nW) during the sensor's asleep-yet-aware phase—an energy drawdown roughly equivalent to the self-discharge (battery discharge during storage) of a typical watch battery, and at least 1,000 times lower than state-of-the-art sensors.

It should also attain a low false alarm rate of 1 per hour or better in an urban environment. Upon detection of a signal having the signature of interest, the N-ZERO component devices must produce a logic state capable of waking up commercial-off-the-shelf (COTS) electronics for further (post wake-up) processing and signal communication.

There are two primary challenges for the N-ZERO program in developing an "OFF-but-Alert" sensor technology. The first challenge is to close the sizable gap between the extremely small signal levels measured by RF and physical sensors and the relatively large threshold voltages required by state-of-the-art comparators. N-ZERO aims to bridge that gap without supplying any active power (≤ 10 nW) in the standby state when the signatures of interest are absent.

The second challenge is the discrimination of the events or signatures of interest from noise and interference, without supplying active power. The critical technologies created by the N-ZERO program are intended to establish methods to provide large passive voltage gain, develop passive signal processing circuits to prevent false detection, and realize comparators operating at extremely low threshold voltages with near zero power consumption enabled by steep sub-threshold swing. This tri-prong approach is intended to result in microsystems capable of detecting and processing signals with near zero power consumption (≤ 10 nW).

DARPA has been able to create zero-power receivers that can detect very weak signals – less than 70 decibel-milliwatt radio-frequency (RF) transmissions, a measure that is better than originally expected. The system has also been able to detect objects correctly without raising a false alarm, which can crimp battery life. In the program's current phase, the sensors need to distinguish between cars, trucks and generators in an urban environment at a close range and in the final phase, they will be required to classify those same targets from 10 meters (33 feet).

"The ability to sense and classify cars, trucks and generators in … both rural and urban backgrounds from a distance of a little over 5 meters away and being able to do that with almost 10 nanowatts of power consumption is a big accomplishment in phase one of the program," Olsson says.

DARPA to develop new IR-based sensor technology

A team of researchers at Northeastern University in Boston will develop a sensor powered by IR energy, as part of DARPA's Near Zero Power RF and Sensor Operation (N-ZERO) programme.

DARPA Microsystems Technology Office N-ZERO Program manager Troy Olsson said: "What is really interesting about the Northeastern IR sensor technology is that, unlike conventional sensors, it consumes zero stand-by power when the IR wavelengths to be detected are not present.

"When those IR wavelengths are present and impinge on the Northeastern team's IR sensor, the energy from the IR source heats the sensing elements which, in turn, causes physical movement of key sensor components. These motions result in the mechanical closing of otherwise open circuit elements, thereby leading to signals that the target IR signature has been detected.”

The IR sensor technology features multiple sensing elements, each of which is adapted to absorb a specific IR wavelength.

These elements combine into complex logic circuits that are capable of analysing IR spectrums, which allow sensors to detect IR energy in the environment and specify if that energy derives from a fire, vehicle, person or some other IR source.

The sensor also includes a grid of nanoscale patches whose specific dimensions limit them to absorb only particular IR wavelengths, DARPA stated.

Northeastern University Electrical and Computer Engineering associate professor Matteo Rinaldi said: “The charge-based excitations, called plasmons (that can be thought of somewhat like ripples on the surface of water), are highly localised below the nanoscale patches and effectively trap specific wavelengths of light into the ultra-thin structure, inducing a relatively large and swift spike in its temperature.”

DARPA Award Funds Richard Shi’s Work to Develop New Low-Power Sensors

Defense Advanced Research Projects Agency (DARPA) grant, University of Washington, EE Professor Richard Shi will be developing specialized sensors that are able to operate with minimal power and remain dormant until triggered.

Through the Near Zero Power RF and Sensor Operations (N-ZERO) program, Shi will develop specialized sensors that are capable of continuously and passively monitoring the environment, with the ability to fully activate in response to specific triggers. Current sensors consume power continuously, which in turn limits the sensor lifetime to months. Expensive batteries must also be frequently replaced.

In addition to current sensors consuming power continuously, a considerable amount of energy is also used by the electronic devices that communicate with the sensors. Therefore, the project will also entail developing radio receivers that are capable of being activated by a radio frequency trigger. Similar to the sensors, this will enable the radio receivers to expand power only when useful information is communicated.

DARPA awards $1.8 million for 'near-zero' power sensors at UC Davis

The U.S. Defense Advanced Research Projects Agency (DARPA) has presented a $1.8 million grant to a project headed by David Horsley, a professor in the UC Davis Department of Mechanical and Aerospace Engineering. The project, "Ultralow Power Microsystems Via an Integrated Piezoelectric MEMS-CMOS Platform," includes the participation of co-PIs Xiaoguang "Leo" Liu and Rajeevan Amirtharajah, both professors in the UC Davis Department of Electrical and Computer Engineering.

Horsley's group has teamed up with InvenSense, the company that makes the motion sensors – gyro and accelerometer – in everybody's smart phones. "DARPA likes to have technology that can be translated into a practical application," Horsley said. "One strength of our program is that we're working directly with a high-volume manufacturer, so the chips we are designing are being made at a production facility and can be rapidly transitioned to production for DoD use at the end of the program."

The program goal is to develop an acoustic sensor and an acceleration sensor that run on near-zero power, producing a wake-up signal when a particular signature is detected: say, a car or truck driving by, or a generator being switched on. "But we don't have to be able to distinguish between any of those vehicles," Horsley noted. "In Phase Two, however, we will have to be able to say, ‘This was a truck’ or ‘This was a car.'”

Horsley said the sensors are “kind of like having the ultimate geophone, where you’re sensing for earthquakes, sensing vibrations in the earth.”

“We have sensors that we’re testing now that are running at below 10 nanowatts,” he said. By way of comparison, the existing sensors in smart phones, although already operating on low power, nonetheless require about 10 milliwatts: roughly 1 million times more power than the sensors being developed by Horsley’s team.

“At the end of Phase One, which will be coming up toward the end of this year, we’re going to deliver the hardware,” Horsley said. “We have a very-low-power acceleration sensor and a microphone that we’re going to deliver to the government, and they’re going to have this independently evaluated at Lincoln Lab at MIT.”

Horsley believes that in the not-too-distant future an ultra-low-powered remote sensor could be triggered by events other than ground noise. One could, for example, have a microphone that’s on all the time listening for a specific keyword. “So one vision for this technology is that … you wouldn’t have to fire up a processor, like an applications processor, or get connected to the cloud to be able to have it do keyword recognition,” Horsley said. “That’s pretty far from where we are now, but it certainly seems like we’re in the right direction to get there.”

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