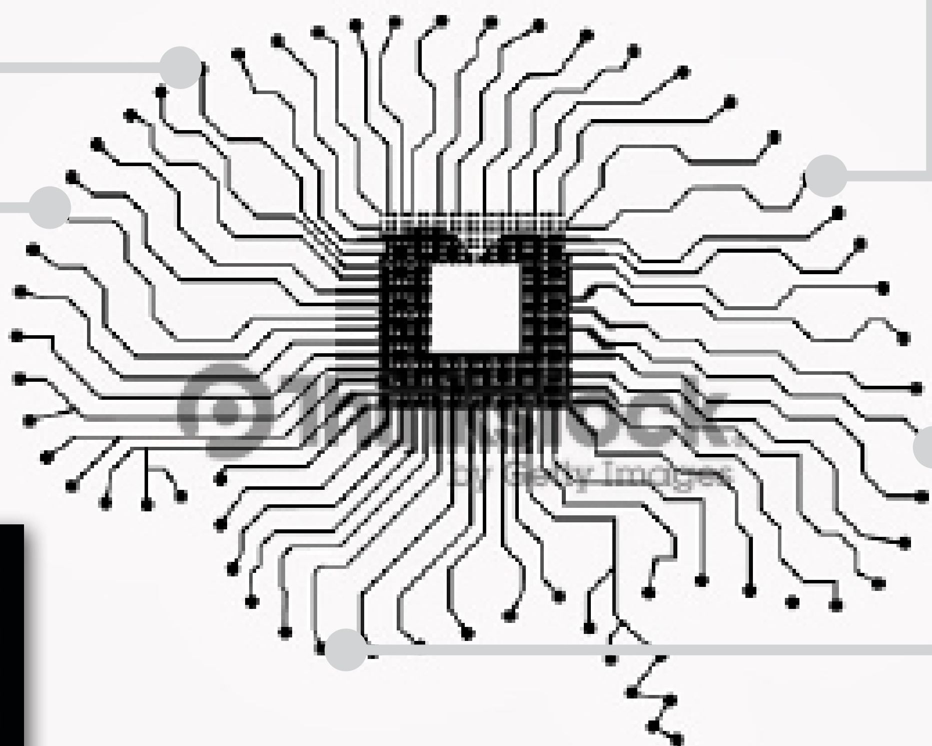
THE CONNECTED LIFE



Shower units can sense your arrival, turn on, and adjust the water temperature.

THE INTERNET OF EVERYTHING: COMING TO A BUILDING NEAR YOU

Bathroom scales, such as Withings WS-50 Smart Body Analyzer, communicate with weight management apps, which can use weight and nutrition information to help control calorie intake.

ONE MORNING NOT FAR IN THE FUTURE, it is nearing time for a sleeper to start the day. Sensors in bedcovers and pajamas monitor sleep patterns. The window system adjusts to let more sunlight enter the room.

At the right moment, a wristband vibrates to wake the sleeper up.

The person steps out of bed and heads to the bathroom where a scale not only reads body weight, but also automatically sends the data to a server in the cloud, where it is available through a smartphone app. The system records personal weight, body fat, food intake, water consumption, and overall activity level.

The person heads to the shower where water is already running at the preferred temperature. At the same time, a message triggers the coffeemaker to start.

While the coffeemaker is grinding fresh beans for the morning cup of joe, the smart phone is transmitting the person's preferred cabin temperature and daily schedule to the smart car, preparing it for the trip to the office.

At breakfast the person uses a calorie counter app on a mobile phone. Scanning the barcode on the oatmeal package records information about calories and nutrition.

In the office, the tasks of the day include a type of data analysis that the person has never done before. The cognitive software assistant offers a step-by-step tutorial for the process, along with names of co-workers who have experience with this analysis.

At the end of the work day, as the person steps out of the office, an embedded beacon sensor sends a notice that a smart phablet has been left on the desk.

As the person heads home, the mobile device reports a 30 percent off sale at a favorite clothing store in the mall. At the store, a scan of the barcode on a suit communicates with the digital inventory system, which confirms that the right size is available in stock.

At the end of the day, from the bed, the press of a single button on the smart wrist watch sends commands that turn off the lights, set the home security system, and adjust the thermostat to a comfortable sleeping temperature.

Welcome to life in the smart city.

Although most of the technology to make this scenario happen is commercially available today, it is interconnectivity and the intelligence of the devices that will make the difference in the future. Embedded sensors will be multipurpose and ever-smaller. Devices will have a higher level of intelligence through deep learning—the system of algorithms that let machines learn from experience and observation.

This interconnectivity—the Internet of Things (or perhaps of Everything)—is expected to have a profound influence on all aspects of life, ranging from transportation and utilities to health care and public services. In a time of increasing urbanization, it is expected to be everywhere in the cities of tomorrow.

Systems informed by sensors, systems that talk to each other, systems that cooperate are envisioned as the means to enhance the day-to-day lives of the citizens. They can also improve innovation, productivity, and economic opportunities by increasing efficiency, lowering costs, and engaging more directly with city dwellers.

Buildings—commercial and residential—are the laboratories leading the trend to smart cities. Almost half the connected

Wifi sensors can alert your coffee maker when you get up and start brewing your favorite blend.

THE FOURTH INDUSTRIAL REVOLUTION: BRINGING BRAINS TO THE SMART FACTORY

The term Internet of Things (IoT) was first coined by Kevin Ashton in 1999 in the context of supply chain management. Physical objects are made "smart" by equipping them with sensors and connecting them to the Internet—a development leading to the gradual replacement of conventional computers and major changes in most aspects of everyday life. Interactions of various systems and devices can already be seen.

The introduction of the connected car is an example of how connection of the vehicle to the Internet enables real-time communication for increased safety and convenience, such as traffic warnings, navigational systems in combination with vehicle logs, and emergency calls in the event of an accident.

The IoT will also have an effect on the way things are produced, and could trigger another industrial revolution. The first revolution followed the introduction of the steam engine; the second was assembly line mass production, and the third was establishing automation via electronic controllers. It is now time for the fourth industrial revolution, or Industry 4.0, a term coined by the German government. In the United States it is often called the "Industrial Internet."

The fourth industrial revolution paves the way for the smart factory, which will consist of networked machines and components under the guidance of intelligent and highly flexible software. Numerous embedded systems will cooperate as if the factory were one integrated machine. Embedded systems link to digital networks permitting independent data processing, improved use of assets, end-to-end automated decision making, mass customization, as well as product and service innovation.

Smart factories act as intelligent networks in which assembly lines have the potential to communicate not just with one another or within a company, but with systems elsewhere and perhaps with the very products being produced. Industrial production machinery will no longer simply process the product. Instead, the product will communicate with the machinery to tell it exactly what to do.

Smart factories rely on the integration of robotics, 3-D design software, and information and communications technologies that will digitize processes to boost efficiency and productivity.

Sensors, software, machine-to-machine learning, and other technologies are used to gather and analyze data from physical objects or other large data streams—and then use the findings to manage operations.

The result will be higher degree of automation, better communication, and precise coordination within factories, in addition to ensuring flexibility in the maintenance, control, and monitoring processes.

The ProGlove combines RFID, motion tracking, and other features. It can scan products, record activities, or alert a worker when a step is incorrectly performed in a workflow sequence.

things in use this year are building systems, and that proportion is likely to grow. Gartner Inc., the information technology research and consulting firm, estimates that by 2020, buildings will account for more than 80 percent of the applications of connectivity.

At the most fundamental level, smart buildings leverage technology and integrate it with processes to deliver useful services to improve the lives of occupants and make them more productive, at the lowest cost and environmental impact.

Smart systems will improve the efficiency of heat, light, sanitation, security, safety, and a host of services. The savings of energy alone could be significant.

IEEE estimates, for instance, that buildings consume roughly 40 percent of the total energy used in the United States and 70 percent of its electricity. Deploying efficiency-enhancing technologies in buildings represents one of the clearest near-term opportunities for large-scale avoidance of greenhouse gas emissions and reduction in U.S. demand for fossil fuels.

Systems such as elevators, HVAC, lighting, and alarms already constantly report data across building networks. There is potential to make greater use of that information to monitor overall building performance, identify trends in building use, and improve customer satisfaction.

For example, an intelligent building could use data from the building security system to turn off lighting and minimize heating or air conditioning when the building is empty.

Connectivity opens a world of possibilities for improving occupant experience, reducing energy costs, and managing building equipment—three areas that can increase returns on real estate assets.

Companies, large and small, are working on solutions for smart commercial and residential buildings. Examples include large companies like IBM, Siemens, Cisco, Intel, and Microsoft, and small ones like TeleSense.

IBM is working with a number of universities, including Carnegie Mellon, to develop cloud-based analytics systems for reducing energy and facility costs in buildings.

The first commercial high-rise smart building in North America is RBC Waterpark Place in Toronto, Canada. Cisco Systems moved its Canada headquarters to that building in May 2015. Cisco will occupy three floors, and the ground floor will hold the company's Internet of Everything innovation center, which will open in September this year.

The building is designed around Internet connectivity. Building services, from lighting and climate control to security and elevators, are monitored and managed through a core network of fiber cabling. For example, lights run off the IP network and not off traditional electric cables, saving considerable amounts of energy. Cables can last for nearly 25 years without replacement, and allow optimal light level output when turned on.

Users can adjust the light level based on their preferences from the control panel, and eventually, even off their own tablet or smartphone. They are able to view their energy consumption and other metrics in real time.

Motion sensors will prevent unoccupied rooms from wasting power on lighting. The net results of Cisco's smart building technology are energy savings and a centralized infrastructure that increases flexibility for tenants using it.

Adolene Inc., a secure IoT platform company in the San Francisco Bay area, is one of the new small companies applying IoT for real-time asset monitoring. The company's TeleSense system focuses on solving three problems in commercial buildings.

First, TeleSense remotely senses temperature, humidity, and air quality thus enabling building managers to make decisions that can improve the occupant experience.

Smart lights by Qualcomm can monitor street traffic and alert engineers if a light malfunctions. It also has acoustic technology that can identify gun shots.

Second, TeleSense monitors energy consumption. It employs advanced machine learning techniques that enable the system to learn the usage behavior of the building and to develop a model that can be used to predict demand and optimize system performance. Usage is optimized through intelligently scheduling the use of HVAC and lighting systems based on occupancy, weather changes, zone temperature variations, dynamic pricing data, and other parameters.

Third, TeleSense monitors vibration, temperature, and acoustics to predict the failure of building equipment, thus migrating from preventive to predictive maintenance.

Technologies for smart connected buildings also include visible light communication, smart glass, and solar panel windows.

Visible light communication, known as light fidelity or Li-Fi, is a wireless optical networking technology that uses light-emitting diodes for high-speed data transmission. It is an alternative to avoid overloaded Wi-Fi networks, replace radio frequency

WaterPark Place in Toronto, where Cisco Systems occupies three floors and hosts an Internet of Things center, has numerous interconnected systems designed to conserve energy and water.

wave connections in certain areas, or provide connectivity in places where electromagnetic wave exposure can be dangerous, such as hospitals, research laboratories, or aircraft. This technology was pioneered by the German physicist Harald Haas, who is now at the University of Edinburgh.

Li-Fi is faster than Wi-Fi; its data cannot be intercepted without a clear line of sight, and it does not interfere with sensitive electronics.

Smart glass aids climate control. Also known as E-glass, it carries a low-voltage current and can adjust the tint of windows automatically. Shading and clearing windows can save as much as 30 percent on the cost of heating, ventilation, and air conditioning.

Smart glass also reduces maintenance costs because there is no need for blinds or shutters. The U.S. Energy Secretary has recommended the use of smart glass in zero-energy buildings, in which the total amount of energy used by the building on an annual basis is roughly equal to the amount of renewable energy created on the site.

Photovoltaic windows are in an early phase. Some current versions can transmit more than 70 percent of visible light, similar to tinted glass windows already in use. The power conversion for the initial designs is low but is expected to exceed 12 percent; typical rooftop solar panels have an efficiency of 15 percent.

One research team calculated that even with 5 percent efficiency the windows could generate over 25 percent of the energy needs of a building. Besides energy generation, the windows can block infrared radiation to reduce thermal loads and energy costs.

Technologies to be commercialized in the future include a new type of fabric created by researchers at the Fraunhofer Institute in Munich. The fabric can detect and precisely locate intrusions in a building and set off an alarm.

Made from a lattice of conductive threads connected to a microcontroller, this smart textile is considerably cheaper than conventional security systems.

In future smart buildings, people will no longer need to switch lights on when they enter a room, or turn off the oven after they bake a cake. These tasks will be done automatically.

Smart connected cities will be the places where sensors of every sort, powerful microcontrollers, and pocket-size supercomputers will be able to measure what people use at any time, with little or no waste. The economy can move away from consuming power and natural resources based on estimates to consumption that is well defined and measurable.

Roads, bridges, traffic signals, electrical grids, homes, and appliances will be connected and will share data to cooperate. In this world, traffic jams, overloads, perhaps even catastrophic structural failures could become things of the past.

Pedestrian detection technology will monitor the volume of people crossing the street and automatically adjust the traffic signal timing.

Vehicles will be networked wirelessly and will be able to broadcast their position and other key data to nearby vehicles. Automobiles can build detailed pictures of what's unfolding around them, revealing trouble that even the most careful driver, or the best sensor system, would miss.

Future smart health care will offer wearable devices for personalized care. The devices will monitor vital signs and give physicians real-time access to a host of patient health indicators.

CONNECTED DEVICES AT CES

At the International Consumer Electronic Show last January, exhibitors showed several ideas taking advantage of the Internet of Things.

Qualcomm showed a smart streetlight that not only lights the street, but also tracks activity and possible crimes. The lights can inform engineers when they've stopped working. A unit incorporates sensitive microphones that can recognize the sound of gunshots. Because the lights are connected, the approximate location of the shot can be pinpointed and authorities alerted immediately.

The company also had connected, communicating trashcans. Qualcomm partnered with smart-trash company BigBelly to fit a garbage bin with sensors that can let pickup crews know it is full. A large solar panel on the top powers an internal compactor to make the most out of the space. Even the door can be remotely locked when it gets full, or potentially in the event of a security alert. There are considerable time, effort, and money-saving opportunities to be had by optimizing routes and collecting historical data on usage.

A collection bin can tell the pickup crew that it is full.

Coca-Cola has developed machines that provide an interactive display, allowing consumers to customize drinks. The machines collect information so Coca-Cola can analyze customers' tastes.

Netatmo, the connected products manufacturer, introduced a home-monitoring camera with face-recognition technology. The tubular camera system offers users a 130-degree field of view. The system can recognize the faces of family members, and will send notifications to an iOS or Android smartphone when someone unrecognizable enters the home. The camera can also live-feed whatever's going on in the house.

Philips showed light bulbs that can be adjusted in color and intensity by smartphone.

LG demonstrated a smart watch that can detect when a person is sleeping restlessly. It can activate soothing music from an audio system, adjust the air conditioner, or pump scented mist from a humidifier.

Connections between things and people, supported by networked processes, will enable everyone to turn vast amounts of heterogeneous data into practical information that can be used to do things that weren't possible before, or to do familiar tasks better.

Cognitive work and service assistants with deep learning and reasoning capabilities will support various human activities.

We can more quickly discover patterns and trends; we can predict and prepare for anything from bus or assembly line breakdowns to natural disasters and quick surges in product demand.

This unprecedented communication can inspire creative thinking and collaborations among businesses and organizations. It can usher in a new era of cognitive knowledge discovery and application (beyond artificial intelligence), intelligent decision making, and service provisioning.

The new era can improve the quality of life and safety of citizens, bring a profound transformation to industry, spur new wave of innovations, and open entirely new dimensions for business processes. **ME**

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TO LEARN MORE

More information on smart cities and the Internet of Things, is available at http://www.aee.odu.edu/smartcities/, and http://www.aee.odu.edu/internetofthings/.

The websites, created as companions to this *Mechanical Engineering* magazine feature, contain links to online material relating to both subjects.