Cities grow smarter through innovative semiconductor technologies

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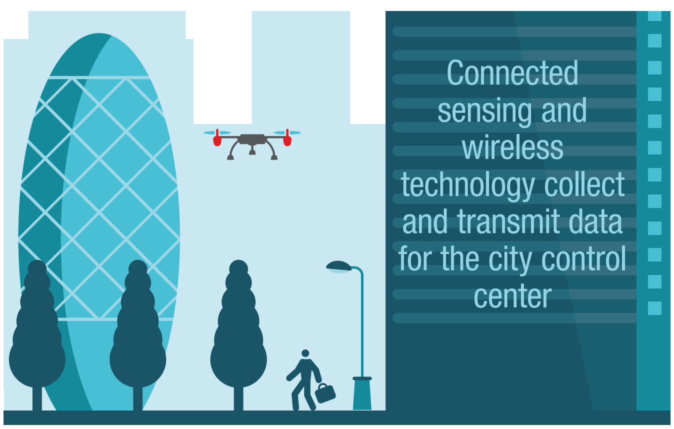
It happens every minute, somewhere, somehow. An accident occurs on the freeway. Traffic backs up for long distances. Ambulances and police cars thread slowly through lines of stopped cars. Cars wait and drivers' frustrations grow.

But what if there were cameras on the street lights poles along the freeway, or drones hovering overhead, that could spot accidents the moment they happen and relay that information immediately to emergency services and traffic control centers? Emergency vehicles would be dispatched immediately. Meanwhile, freeway signs would signal lane closings and alternate routes on other streets, where traffic lights would be retimed to handle the greater traffic flow. Radar sensors would detect lanes with blocked traffic, and cars communicating with the traffic infrastructure would be rerouted automatically in order to keep everyone moving. Police and medical assistance would arrive quickly at the scene of the accident to clear the road and treat victims, saving precious time that would be lost if response times were slower.



This scenario illustrates only one feature of the smart city, a metropolitan area that relies on a seamless web of electronic technology to make it safe, clean and efficient. Cities already have networks for traffic control, city services, power, communications and a number of other purposes. The vision of the smart city is to integrate these and augment them to help the city operate smoothly while saving money and energy. Along with controlling operations for everyday services such as traffic flow, water consumption and waste management, smart city networks will be regulating local power generation and storage, as well as constantly collecting data to improve energy use and how we handle pollution, crime and emergencies.

Today, cities in some parts of the world are being designed with smart city features. Established metropolitan areas are also rapidly adding greater sensing, communications and processing to existing networks, while extending this intelligence to include new services. Like smart homes, factories and cars, smart cities are appearing incrementally and, in fact, will increase communications with smart buildings and vehicles to gather data and function more effectively.

Texas Instruments (TI) provides the innovative technology to help enable the evolution of smart cities, supporting every stage of the signal chain, including sensing, signal conditioning, control processing and communications. As cities grow smarter, these technologies play an invaluable role in meeting ever-more sophisticated requirements and creating capabilities that were previously not thought possible.

Smart city services

The number of applications to aid municipal services is potentially never-ending, but certain types of services are frequently mentioned in smart city discussions. Among these are planning, traffic control, parking, creation and distribution of power, energy usage, maintenance of public areas, water and waste management, and public safety and security.

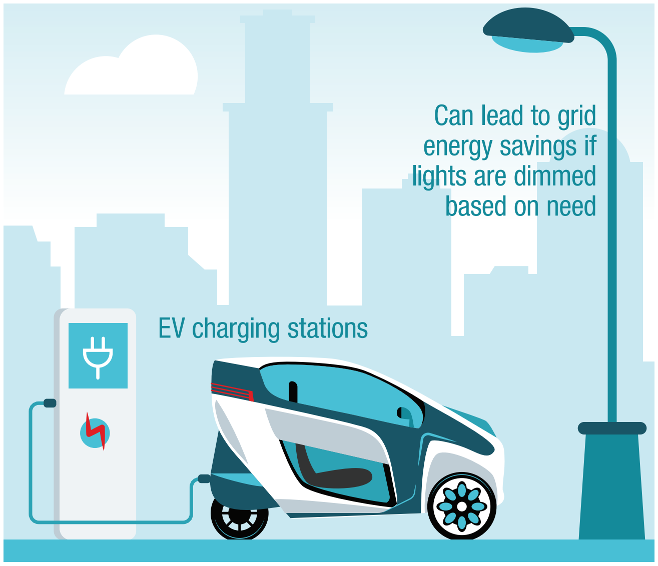
Planning. According to a United Nations[1] report, in 2014 there were 28 megacities worldwide, each with more than 10 million residents. By 2030, the number of megacities is projected to increase to 41. As cities continue to grow, accurate planning is vital. Data gathered from all the above areas and others can help citizens and their representatives prepare for the needs of their cities in the future.

Traffic. The scenario above illustrated several uses of technology to help keep traffic moving: cameras and sensors at key locations along roadways such as:

- Street lights, signs, bridges and traffic drones
- Wired and wireless networks that relay information from these input nodes to gateways and from there to the Internet cloud and municipal control centers
- Communication to emergency services, vehicles, electronic signs, traffic lights, actuated traffic barriers and so forth

As cars become more intelligent, and ultimately autonomous or self-driving, they will communicate with the roadway to learn about conditions ahead and alternate routes. Expressways may ultimately take control of automated vehicles wirelessly to keep traffic flowing smoothly and safely. In intersections and crowded areas, traffic monitors may manage vehicles. For example, these monitors could instruct a car to swerve or stop to avoid a pedestrian who carelessly steps in the road while looking at a phone screen.

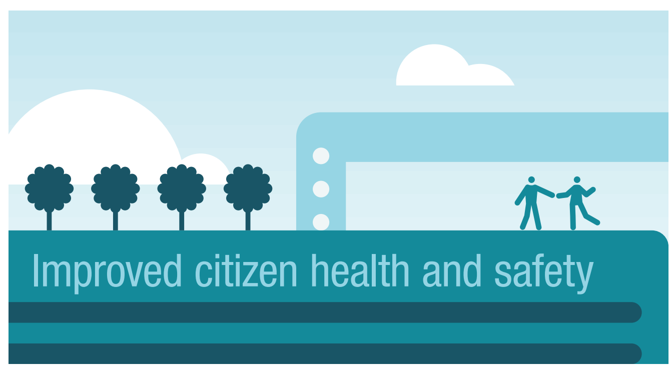
Parking and recharging. One of the major headaches of driving can be finding where to park. Smart parking lots with radar sensors can spot vacancies and direct incoming vehicles to open spaces, even reserving spaces by network for cars before they arrive to the lot. As electric vehicles (EVs) become more common, some spaces will offer plug-in or wireless battery charging that can be reserved and paid by network. Fleets of robot cars, which will spend the day fetching and delivering passengers, can return to spaces with wireless charging between trips to top up their batteries.



Electric power. As alternative energy sources come online, production of electricity is rapidly becoming more distributed. Homes and commercial buildings with solar panels often have options for selling excess production to the grid. Batteries are gradually becoming less expensive, promoting local storage, both stationary and mobile. All of these sources of energy harvesting and storage require power conversion and management. At the same time, the greater complexity of the overall picture for energy collection and distribution demands sophisticated management over a wide area. Among the advantages will be fewer blackouts and brownouts, since local sources of power can help compensate when delivery of electricity from central plants is interrupted. While electric companies will be responsible for installing and operating most of these applications, local governments will also contribute significantly as regulators and influential customers.

Energy efficiency. In addition to electricity generation, usage has to be controlled. The power grid will monitor devices and collect data to help optimize energy use continuously throughout the metropolitan area. Public and private properties will all benefit, with measures that entail not only efficient building heating, cooling and lighting but also other types of applications. Street lights, for example, could be designed to adjust illumination in keeping with time, traffic flow, ambient light and weather conditions. They could also predict and report maintenance issues, as could traffic lights and other types of electrical systems.

Infrastructure maintenance. Cities everywhere have to maintain vast numbers of public structures such as bridges, road surfaces and buildings. Electronic sensors that monitor vibrations and report wirelessly to the city network can help maintenance engineers predict stress failures and arrange for timely repairs. Networked cameras can report the condition of open spaces such as parks and plazas, helping the municipal authority stretch its budget to keep public areas clean and safe and plan for usage and expansion. The same kind of monitoring can aid city inspections of private premises and provide valuable information concerning needed or outdated structural regulations.



Water, waste, pollution. Fresh water has become increasingly scarce in some areas, while at the same time, waste is becoming all too plentiful. The mandated use of gauges to monitor and control water usage by sprinklers will continue to increase, aided by intelligence that decides how much water can be used, according to availability. Waste removal services may eventually rely on sensors that report where and when garbage needs to be collected, based on the contents or fullness of trash containers, helping make the process more efficient. Sensing and controlling pollution, already critical, will become even more so as metropolitan areas swell from millions to tens of millions of inhabitants.

Safety. Virtually all city services in some way affect the safety of residents and commuters. Through traffic controls, street lighting, security cameras in public areas, monitoring infrastructure for maintenance, and even control of services, such as power, water and waste, the smart city employs technology to enhance the safety and comfort of those within its borders.

Technical requirements of smart cities

In many ways, smart cities depend on the Internet of Things (IoT) applied on a city-wide basis. That is, innumerable sensors and small systems communicate constantly through gateways and the Internet cloud to metropolitan control centers to keep city services running smoothly. As with the IoT, the technology required for individual sensing nodes in smart cities has to be miniature and affordable, while consuming very little power in operation. Further upstream from the nodes, in gateways, and especially in the cloud and control centers, high-performance, high-bandwidth and multichannel operation become increasingly important. Equipment manufacturers for smart cities, and the municipal governments who are their customers, will have to look for scalable electronic solutions that meet these requirements.

Remote sensors are normally small and cannot be routinely maintained for battery changes. Sensors vary in complexity, but a given sensor may combine one or more sensing elements for temperature, sunlight, radar, lidar or chemical detection, together with analog-to-digital conversion (ADC) and signal amplification, local processing, a communications interface, wireless transmission, a battery and power management. These functions must fit in the space of a button that can be applied to a pole, beam, wall or other structure, where the sensor can perform its function for years without interruption or failure.

To accomplish these goals, sensors rely on ultra-low-power ICs that prolong battery life or allow the use of energy harvested from ambient conditions such as sunlight or vibration. A sensor may wake up for a brief time to sense, digitize inputs and communicate data, then go dormant again from seconds to hours before repeating the cycle. Communications may be performed at very low bit rates to conserve power. As these sensors are often in remote locations, wireless communication plays a pivotal role in enabling a wide spread net of sensors, driving the need for stable technologies with optimized low power requirements.

Digital video cameras produce a large data stream, making bandwidth- and power-reduction techniques especially important. Cameras can wake up at intervals, or only when motion is detected. Frames can be scanned within the unit for objects of interest, allowing selection of only the most essential information for transmission. Advanced compression techniques keep to a minimum the bandwidth needed for communication. Object recognition and compression are enabled by video processors with acceleration for high-speed signal processing.

Gateways that aggregate transmitted data from multiple sensor and camera nodes, are processing-intensive. These units require high-performance microprocessors to evaluate data received from the nodes and determine whether to take action locally. For instance, a gateway that controls part of an expressway may have to re-route traffic lanes, as well as feed combined data upstream via the cloud to the traffic control center. Although gateways are normally line-powered, they still benefit from low-power electronics, which allow the units to perform more functions in a smaller space without creating excessive heat. Gateways may also require high-speed, multichannel communications to keep in touch with nodes and upstream control centers.

The control centers themselves demand even more intensive communications and processing from the highest-performing IC devices. Control centers, and the cloud in general, require easy-to-program and scalable solutions to support the ever-changing needs of city services. These include multicore microprocessors with hardware dedicated to principal signal-processing tasks, flexible communications interfaces and highly efficient power management.

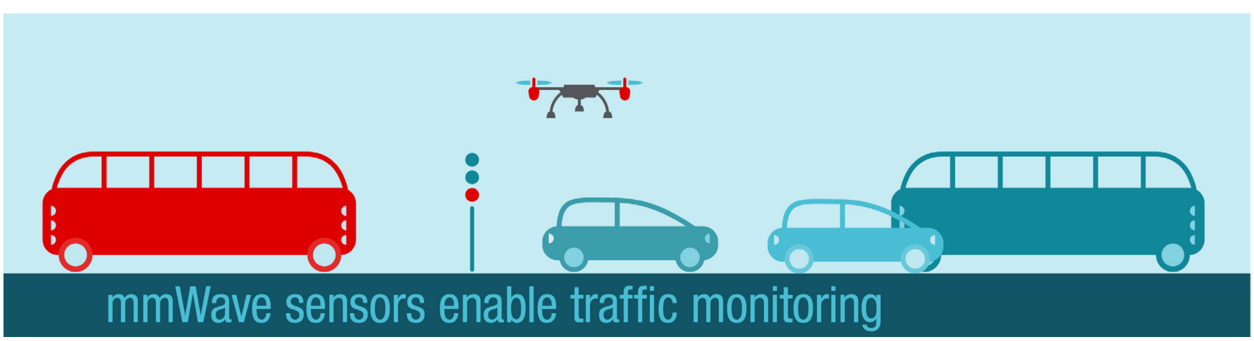
Finally, all systems, from the smallest sensors to building-scale solar generating facilities, require power management functions to supply operating power and use power efficiently.

TI solutions for smart city networks

Because technical requirements of smart cities are so varied, solutions providers must have at their disposal a range of manufacturing and design technologies that can be scaled to the demands of different applications. TI, with a broad portfolio of analog and mixed-signal products, plus high-performance signal processing and microcontroller devices, provides innovative offerings across the complete signal chain, including sensing, signal conditioning, processing and communications. TI technology enables continuous advancements in the areas of low-power consumption and high performance, as well as integration of different functions for miniaturization and affordability. Some of the key technologies TI offers for smart cities include:

Sensors. TI sensors gather data covering a wide range of conditions. Sensors contain sensing elements, signal conditioning and communications, and many add processing, depending on requirements. A few highly integrated examples are the recently released IWR1x and AWR1x portfolios of millimeter wave (mmWave) radar sensors, which deliver up to three times more accurate sensing than previously available mmWave solutions. The single-chip devices combine sensing technologies, signal conditioning and data communication, an example being the PGA900 programmable sensor conditioner. mmWave radar plus single- or multicore microcontrollers (MCUs) and digital signal processors (DSPs), allow designers to implement intelligent, contactless sensing to help vehicles interact and avoid other cars, people or objects on the road. Reference designs include the TIDEP-0092 for smart cars in smart cities, and the TIDEP0090 IWR1642 for traffic monitoring. Other modules include the TIDA-00561, with a wireless pH transmitter for process control, and the TIDA-00851, a single-chip solution for temperature measurement and transmission for small and easy implementations.

Signal conditioning. Analog input signals have to be optimally conditioned by operational amplifiers (op amps) and ADCs. TI's analog expertise and



advanced manufacturing enable one of the widest, most advanced selections of low-power conditioning functions available. Among solutions for sensor conditioning is the LPV81x family, the industry's first precision nanopower op amps for low-power applications. ADCs for a variety of applications span the range from high speed and precision to ultra-low power for use in sensors.

Low-power control sensing. TI's MSP430™ MCU platform, the industry's broadest ultra-low-power MCU portfolio, offers advances in performance, integration and ease of design well-suited for smart city sensing and measurement applications. The unique Low-Energy Accelerator (LEA) module in MSP430FR5994 MCUs enables users to employ DSP-powered complex functions without DSP programming, boosting performance of these algorithms by 40 times. Integrated application-specific devices include the ultra-low-power MSP430FR6047 family of ultrasonic sensing and measurement MCUs that provide high accuracy for flow rates in water and gas meters.

High-performance computation. For advanced systems such as gateways, smart grid protection relays and the cloud, TI offers its Sitara™ processor family to meet a range of requirements for smart cities. Based on ARM® Cortex®-A cores, these scalable processors offer flexible peripherals, connectivity, unified software support and security options. The AM335x processor combines performance and cost-efficiency; the AM437x processor offers real-time throughput; and the AM57x processor delivers connectivity and multimedia.

Video. To keep pace with a high data stream, video cameras depend on fast signal conditioning and high-performance video processors. TI's recognized leadership in analog functions and DSP technology allows the company to provide advanced video solutions. For embedded systems, Sitara processors provide hardware acceleration of video algorithms to provide fast compression, object recognition and other key video tasks.

Network communications. While most sensors can rely on wireless communications, the data streams produced by cameras often require wired networking. TI develops innovative offerings to address both types of networks using the SimpleLink™ MCU platform. The platform of hardware, software and tools provides a single development environment with full code reuse across wired and wireless designs. From low-power host controller and wired communications support with the MSP432™ devices, to support for *Bluetooth*® 5, ZigBee®, Sub-1 GHz, and emerging standards like Thread with the CC26xx and CC13xx wireless MCUs, the SimpleLink platform allows the whole system to be built and easily configured for the required connectivity technology with a common software update mechanism, application program interfaces (APIs) and development environment.

Power solutions. TI's wide portfolio for power conversion and management covers voltages ranging from below a single volt up to hundreds of volts. An example of TI's leadership in high-voltage solutions is the UCC21520 isolated dual-channel gate driver, which drives various types of power switches with best-in-class propagation delay and pulse-width distortion. Designers of applications such as EV chargers can turn to the TIDM-1000 Vienna reference design with three-phase power factor correction, which controls rectification using C2000™ MCUs. Similarly, the TIDM-1001 reference design uses C2000 MCUs to achieve high performance and high power density in two-phase interleaved LLC resonant conversion in a wide range of power supplies.

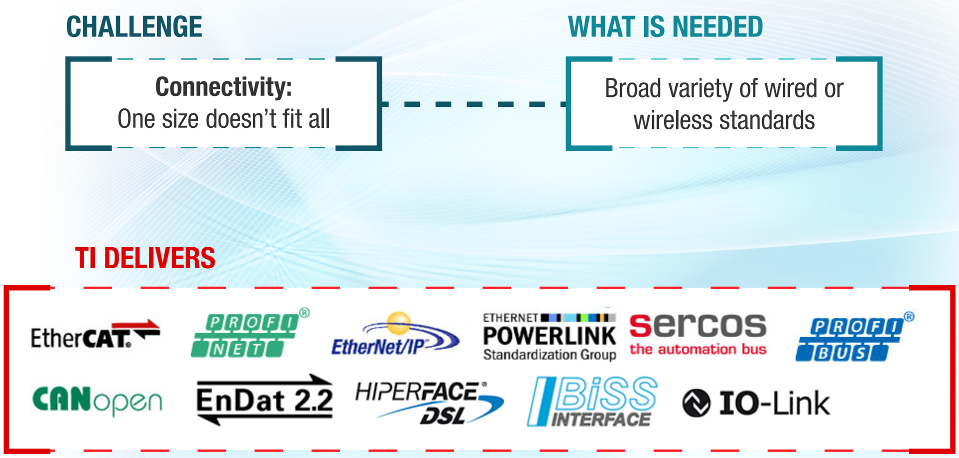


Figure 1. Industry 4.0 wired and wireless connectivity.

Providing dedicated power for MPUs are devices such as the TPS65218 power management IC (PMIC), designed for versatility in portable and fixed applications.

Functions that aid remote sensors include battery management and energy harvesting devices, such as the bq25570 and bq25505 energy harvesting ICs used for charging from solar cells and other ambient energy sources. The TIDA-00757 Smart Lock reference design brings DC-to-DC conversion with an extremely low quiescent current that can enable five years operation from four AA batteries. The TIDA-00690 reference design implements a wireless switch with energy harvesting, and the TIDA-00246 module offers a generic power solution for energy harvesting. These and other solutions are tailored to achieve extremely low power consumption in sensors and other power-sensitive applications.

Protection. High levels of integration mean that signals of widely different voltages and frequencies need to be isolated from each other for signal integrity and the protection of people and equipment. TI offers options for integrated reinforced isolation in its power portfolio and elsewhere.

Components used to implement protected and reliable solutions include, for example, the 8-channel ADC8688 signal conditioner, with 16-bit resolution, a high sampling rate and wide input range, which is used in distributed grid, among other applications. The TIDA-01333 reference design offers a very small implementation for isolating analog signals and power.

Development support. To simplify development and help speed time to market, TI provides numerous evaluation modules (EVMs), reference designs and development tools other than those mentioned above, plus extensive documentation and worldwide regional support.

Smarter cities ahead

Intelligent electronic management of cities has been growing for a long time, but the vision for the smart city moves this trend far ahead. In the future, metropolitan networks for power, communications, transportation, resource management and other services will be integrated, and all of these areas will be served by countless points of information collection feeding into the internet cloud. Cities will be able to manage their services more efficiently, better satisfying their residents more cost effectively.

The vision of the smart city depends on sensors, gateways, control centers and the cloud communicating efficiently through a mesh network with hierarchical elements. Each data gathering, aggregation or decision point will have its own requirements that can only be met through flexible, scalable semiconductor solutions. TI, with its systems expertise and advanced technology throughout the signal chain, continues to offer innovative products that work together to enable smart city networks. Cities are indeed growing smarter, and TI's commitment to innovation is helping them evolve.

For more information about smart cities and the products and reference designs that enable them, visit:

- Our interactive smart cities infographic
- TI sensing, power management, and embedded processing products
- TI's system solutions for grid infrastructure, lighting and connectivity

References:

Footnote 1: www.un.org/en/development/desa/news/population/world-urbanization-prospects.html

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