Chapter 2

Ubiquitous IoT Applications

2.1 A Panoramic View of IoT Applications

We talked about the big picture and megatrends of the Internet of Things (IoT) in the first chapter, and now we are going to describe the vastly large number of IoT applications and related technologies in a variety of fields in greater detail.

Telemetry is an "ancient" technology that allows remote measurement and reporting of information. Although the term commonly refers to wireless data transfer mechanisms, it also encompasses data transferred over other wired media. Telemetry is synonymous with IoT to some, and it can be regarded as one of the earliest IoT applications. It is closely related to and intertwined with other IoT technologies and applications such as machine-to-machine (M2M) and supervisory control and data acquisition (SCADA). One of the first telemetry applications was developed in 1845 between the Russian czar's Winter Palace and the army's headquarters. In 1874, French engineers built a system of weather and snow-depth sensors on Mont Blanc that transmitted real-time information to Paris. Telecommand and telematics (telecommunication + informatics) were more related to telemetry in earlier times. However, telematics nowadays often refers to vehicle tracking, especially passenger car tracking and global positioning system (GPS) services.

Most recently, the IoT is increasingly finding its way into mainstream news. Executives of large companies and even government officials, such as President Obama and the Chinese premier, are speaking about the possibilities and opportunities of having ubiquitous sensors connected to the Internet.

"The next big revolution that will happen is the Internet of Things," said Cisco chief technology officer Padma Warrior. Although the widespread adoption of IoT will take time, the time line is advancing thanks to improvements in underlying technologies. Advances in networking technologies and the standardization [31] of communication protocols, XML-based data representations, and middleware architectures make it possible to collect data from sensors and devices almost anywhere at any time. Ever-smaller silicon chips are gaining new capabilities, while costs are falling. Massive increases in storage and computing power, available via cloud computing, make number crunching possible at a very large scale and at declining cost. It's easy to speculate on possibilities:

- Radio-frequency identification (RFID) tags that know where your luggage is
- Mesh networks of sensors that can more reliably monitor the changing concentrations of volcanic ash
- Heating, ventilating, and air-conditioning (HVAC) units that can coordinate to act in concert, rather than independently
- Smart sticking plasters that detect microscopic changes in skin condition or blood flow
- An in-vehicle terminal or called an edge device that can detect if you are too sleepy to drive safely

- Surveillance systems that can analyze what they are filming, being alert for security abnormalities
- Smart glasses for the visually impaired that can interpret what you're looking at
- A toothbrush that can let you know if you're not putting enough effort into cleaning the inner sides of your lower right molars
- And all of these devices connected together …

The arrival of the IoT concept and its worldwide attention is closely relevant to environmental, societal, and economic challenges such as climate change, environment protection, energy saving, and globalization. For these reasons the IoT is increasingly used in a large number of sectors. Key sectors in this context are transportation, healthcare, energy and environment, safety and security, logistics, and manufacturing. M2M and embedded mobile devices are sending mobile data to servers that are increasingly useful and valuable to ERPs [34].

Harbor Research segments the IoT/M2M market into 10 key sectors [32], 30+ subsectors, and countless systems and devices:

- Buildings: Institutional/Commercial/Industrial/Home. HVAC, fire and safety, security, elevators, access control systems, lighting
- Energy and Power: Supply/Alternatives/Demand. Turbines, generators, meters, substations, switches
- Industrial: Process Industries/Forming/Converting/ Discrete Assembly/Distribution/Supply Chain. Pumps, valves, vessels, tanks, automation and control equipment, capital equipment, pipelines
- Healthcare: Care/Personal/Research. Medical devices, imaging, diagnostics, monitor, surgical equipment
- Retail: Stores/Hospitality/Services. Point-of sale terminals, vending machines, RFID tags, scanners and registers, lighting and refrigeration systems

- Security and Infrastructure: Homeland Security/Emergency Services/National and Regional Defense. GPS systems, radar systems, environmental sensors, vehicles, weaponry, fencing
- Transportation: On-Road Vehicles/Off-Road Vehicles/Nonvehicular/Transport Infrastructure. Commercial vehicles, airplanes, trains, ships, signage, tolls, RF tags, parking meters, surveillance cameras, tracking systems
- Information Technology and Network Infrastructure: Enterprise/Data Centers. Switches, servers, storage
- Resources: Agriculture/Mining/Oil/Gas/Water. Mining equipment, drilling equipment, pipelines, agricultural equipment
- Consumer/Professional: Appliances/White Goods/Office Equipment/Home Electronics. M2M devices, gadgets, smartphones, tablet PCs, home gateways

Machina Research classified the IoT/M2M market into 3 categories and 11 segments [35]:

- Intelligent Environment: Intelligent buildings/smart cities and transportation
- Intelligent Living: Automotive/consumer electronics
- Intelligent Enterprise: Health/utilities/manufacturing/retail and leisure/construction/agriculture and extraction/emergency services and national security

Per the IoT definition of the previous chapter, the goal of IoT is to achieve pervasive M2M connectivity and grand integration and to provide secure, fast, and personalized functionalities and services such as monitoring, sensing, tracking, locating, alerting, scheduling, controlling, protecting, logging, auditing, planning, maintenance, upgrading, data mining, trending, reporting, decision support, dashboard, back office applications, and others. Those functionalities are common features of IoT systems supported by a common three-tier IoT system architecture that will be described in the latter part of the book.

Beecham Research tracks nine key industries and their associated devices using all principle technologies for connecting them [33]. Such devices range from air-conditioning, access control, and lifts and escalators in the buildings sector to wind turbines, utility meters, and pipelines in the energy/power sector and to closed-circuit television and lone worker solutions in the security/environment sector; from magnetic resonance imaging (MRI) scanners, x-ray machines, and blood analyzers in the healthcare/life sciences sector to telematics systems for cars, trucks, containers, and off-road vehicles and road toll schemes in the transportation sector.

A panoramic view of the IoT applications is shown in Figure 2.1 based on summarizing most of the previously

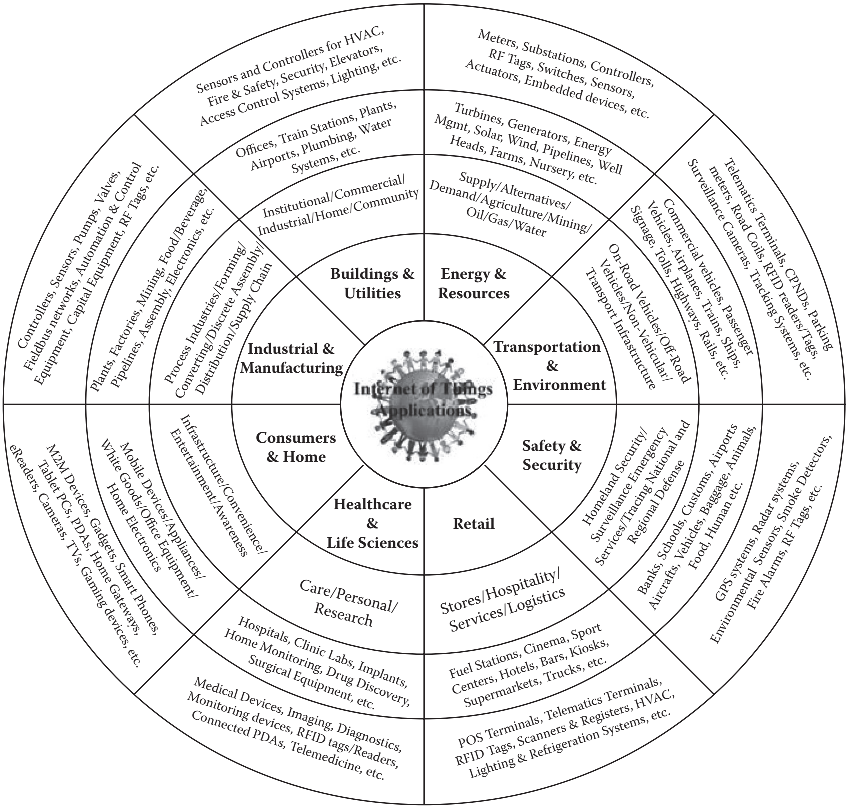

Figure 2.1 A panoramic view of IoT applications.

described industry categories and segments. The first ring is the sectors, the second ring is application groups, the third ring is target objects or sites, and the fourth ring is devices used.

As we see from the previous paragraphs, the term Internet of Things is sometimes used interchangeably with M2M by some market research firms. M2M can be regarded as one of the four sectors under the IoT umbrella; the other ones include RFID, wireless sensor networks (WSN), and SCADA (or called smart systems, industry automation, etc.). Currently, even though almost everyone believes that the IoT market is a huge market, few research reports about the size of the entire IoT market as defined in the last chapter have been produced by market research firms.

Some research firms have reports on two or three of the four IoT sectors, but not all of the four sectors. For example, Harbor Research forecasts that the smart systems [186] and M2M market value will be €280 billion in 2013.

Analysys Mason, a trusted adviser on telecoms, technology, and media, predicts that by 2020, North America will have the most devices per person, with the highest estimate predicting as many as 23.2 devices per person in the region. The Middle East and Africa are expected to have the fewest devices, where estimates are as low as 0.2 per person. The total IoT devices deployed in 2020 will reach 16 billion, a relatively conservative number compared with other predictions. Despite the forecasts for aggressive growth, the IoT has yet to become a mass-market proposition. The IoT still needs to be pulled together into a cohesive and user-friendly package, while security issues also need to be resolved.

Those are predictions tagged with IoT but not necessarily the entire IoT market. However, there are market research reports on the four subsectors of IoT. Several individual market reports will be covered in the next chapter.

Having seen the great potential of the IoT market, many vendors, old and new, have joined forces in this market. A map of comprehensive clusters of IoT vendors based on their focus and position can be found in a publicly available Harbor Research [37] report. The *Connected World Magazine* has published an M2M Top 100 list [188] every year since 2004 [39]. The name of the magazine was changed from *M2M Magazine* [187], which indicates a paradigm change from M2M to a broader IoT coverage. Also, there is a Top 10 list of IoT development for the last two years [190]. Hewlett Packard's Central Nervous System for the Earth was number one on the list in 2010.

2.2 Important Vertical IoT Applications

Before describing the common horizontal technologies underpinning the Internet of Things, we are going to describe some of the important and representative IoT applications in more detail as examples to give the reader more insight and to demonstrate the power and capabilities of IoT technologies or ideologies.

2.2.1 Telematics and Intelligent Transport Systems

Telematics and intelligent transport systems (ITS) are closely related. The IoT technologies and ideologies can be used in telematics as well as ITS, especially in promoting their seamless integration. Telematics and ITS have been a kind of IoT application for a long time. The combined application is called *automobile IoT* in China. It was reported that "the Automotive Mobile Internet of Things has been set as a major project among all the important national projects. At present the relevant materials have been submitted to the State Council. The first batch of funds may total up to ten billion Yuan. By the year of 2020, the amount of controllable (connected) vehicles will reach up to 200 million units." Figure 2.2 shows the scope of China's automobile IoT, which is different from Vehicular Networks [273].

Telematics can be categorized as a subsector of LBS (location-based service; a list of traditional technology-based

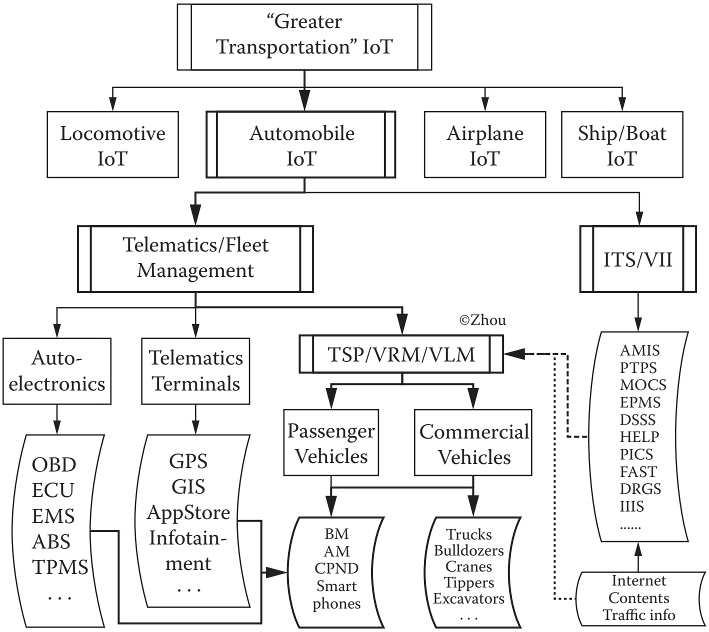

Figure 2.2 Telematics/fleet management/ITS and IoT.

players can be found at http://etutorials.org/Mobile+devices/mobile+wireless+design/Part+Four+Beyond+Enterprise+Data/Chapter+17+Location-Based+Services/LBS+Vendors/; LBS has also been part of social networking services recently with players such as FourSquare and locationary.com). Telematics, as determined by its name, is any integrated use of telecommunication and informatics (Figure 2.3). Its application is within any of the following:

- The technology of sending, receiving, and storing information via telecommunications devices in conjunction with effecting control on remote objects, especially for application in vehicles and with control of vehicles on the move
- GPS technology integrated with computers and mobile communication technology in automotive navigation systems
- The use of such systems within road vehicles, including commercial and (particularly) passenger vehicles

Figure 2.3 Telematics terminal.

The development of auto-electronics as well as telematics has driven the automobile industry into a so-called third-wave automotive industrial revolution. The first automobile revolution was about power, using a high-compression-ratio engine. The second automobile revolution was about control, using microelectronic devices for electronic fuel injection, cruise control, and emission control. And the third revolution is about connectivity (just like M2M) based on telematics for navigation, Internet, ITS integration, and so forth (Figure 2.4).

As of 2010, the cost for vehicle electronics is as high as 40 to 50 percent of the total cost for some vehicles. This is up from 20 percent less than a decade ago [41]. In some luxury cars, the number of microprocessors has reached 50, connected with hundreds of sensors. The sensors and actuators in the vehicles for the monitoring and control of critical units such as the brakes, battery, door locks, safety and security systems, audio/video systems, remote vehicle control, navigation, diagnostic and emission control systems, and others are connected with standard-based buses such as CanBus, LIN, FlexRay, and MOST to the electronic control unit. Types of sensors and actuators in vehicles include sensors and controllers for crash avoidance such as adaptive cruise control

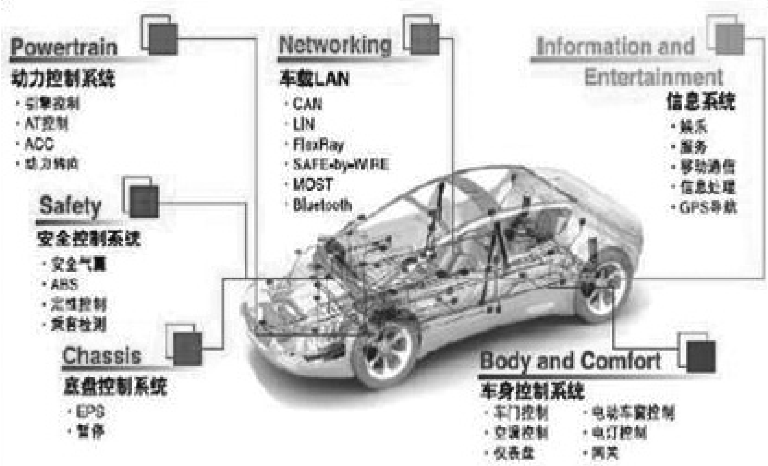

Figure 2.4 In-vehicle networking.

radar, convenience such as remote keyless entry, comfort such as HVAC control, engine sensors such as inlet manifold pressure controller, hybrid and fuel cell such as hydrogen leak detection sensors, vehicle control such as latitude/longitude acceleration controllers, and safety and security such as tire pressure monitoring.

Estimates indicate that the total number of cars owned around the world will reach 1.5 billion in 2020, excluding commercial vehicles and engineering equipment, which account for about one third of the number of cars, making the total automobile number to be around 2 billion in 2020. As the price of telematics terminals keeps going down, it can be expected that telematics terminals with GPS and infotainment capabilities will be a standard device in vehicles just as the radio and CD player are today. This is an enormously huge market.

Auto-electronics exist within a vehicle. Telematics, as a typical M2M application, connects many vehicles to a central server to form a connected vehicle system that provides many services. Organizations providing such services are often called telematics service providers (TSPs). Some of the

Figure 2.5 Telematics functions/services.

functionalities and services provided by a TSP are shown in Figure 2.5.

NGTP (Next Generation Telematics Pattern, http://www.ngtp.org/) is an open protocol and standard for telematics system architecture created by BMW, Connexis, and WirelessCar. The components of TSP are described in NGTP 1.0 and 2.0 (even though the name is changed to SI in 2.0). Table 2.1 shows a list of major telematics brands.

The telematics terminals can be categorized into BM (before market), AM (after market), and PND (portable navigation device) units. The BM units come with the original vehicle manufacturer and the AM units are integrated into the vehicles later as requested by the vehicle owner. As an indicator of the market size, ABI Research estimates that PND shipments will number more than 150 million units in 2013. However, as more and more telematics device become standard equipment

Table 2.1 Telematics Brands Worldwide

Regions	*Regional Characteristics*	*Telematics Brands*	*Manufacturer Ownership*
USA	1. Vast land 2. Four wireless communications systems coexist	OnStar	GM
		SYNC	Ford
		Connexis	Ygomi independent
		Hughes Telematics	Independent
		Airbiquity	Independent
EU	1. Multilanguage support 2. GSM majority	Tegaron	Daimler Chrysler
		Targa	Fiat Auto
		ATX	Daimler&BMW
		Wireless Car	Volvo Independent
Japan	1. High population density	Internavi	Honda
		CARWINGS	Nissan
		G-BOOK ALPHA	Toyota

from the original vehicle manufacturers, that is, the AM market share is increasing, the PND market has been declining [195].

Figure 2.6 shows a typical architecture of a telematics terminal. A general-purpose embedded middleware layer is often constructed to simplify the development of various and ever-changing applications. Java technology and the universal OSGi middleware framework are often used together to build the embedded middleware.

GENIVI (http://www.genivi.org/) is a nonprofit industry alliance committed to driving the broad adoption of an in-vehicle infotainment (IVI) reference platform. The GENIVI platform—a common software architecture that is scalable

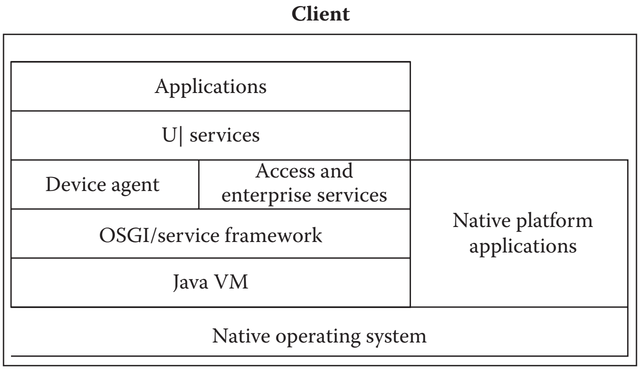

Figure 2.6 Telematics terminal architecture. (From Paolo Bellavista and Antonio Corradi (eds.), *The Handbook of Mobile Middleware,* New York: Auerbach Publications, 2006.)

across product lines and generations—will accelerate the pace at which new and compelling automotive applications are developed and allow new business models to emerge in the in-vehicle infotainment market. It consists of Linux-based core services, middleware, and open application layer interfaces and establishes a foundation upon which automobile manufacturers and their suppliers can add their differentiated products and services.

However, as the iOS and Android application store model become popular, more and more terminals are built on top of Android. The smartphone, the PDA/PC, and the telematics terminal could converge into one screen in the future.

Based on the well-known Gartner hype cycle graph (http://www.gartner.com/technology/research/methodologies/hypecycle.jsp), telematics has passed the hype cycle that happened around 2001, beginning in 1997 when General Motors launched OnStar. The revenue of OnStar surpassed the $1 billion mark in 2010. It is believed that OnStar is the only business unit of GM that didn't lose money from 2005 to 2010. The telematics industry is now on track with healthy and steady developments.

Table 2.2 Fleet Management Brands and Vehicle Manufacturers

Products & Services	*Owners & Providers*
Daimler FleetBoard	Daimler FleetBoard GmbH
Ford CrewChief, Tool Link	Ford Motors
Dynafleet, CareTrack	Volvo (WirelessCar)
JDLink	John Deere
ProductLink, RAC, VIMS	Caterpillar
AWARE Vehicle Intelligence	Navistar (Electronics)
Blue&Me Fleet	Fiat Iveco
Scania Fleet Management	Scania
Squarell Fleet Management	DAF, MAN (third party)
TeloGis, FleetMatics, CFA	Independent third parties

Fleet management, especially GPS-based fleet tracking, is thought by some people as a subsector of telematics known as fleet telematics. However, in some refined market reports, fleet management is regarded as a separate market. The iSuppli corporation market research report lists "Vehicle Tracking and Fleet Management" and "Automotive Telematics" as two markets, with the size of the former market slightly bigger than the latter. ABI Research estimates that the fleet management market is expected to have more than 35 million service connections worldwide in 2013.

Fleet management is for commercial vehicles what telematics is for passenger vehicles. Table 2.2 lists the major truck and engineering equipment manufacturers and their fleet management products and services developed in-house or provided by third parties.

Fleet management (and also telematics) is a subsector of MRM (mobile resource management), which is itself a subsector of the M2M business. According to a 2009 report of C.J. Driscoll & Associates—

- More than 225,000 companies used MRM systems and services at the end of year 2008 in the United States.
- An estimated 3.6 million units are in service with a $1.8 billion market, 75 percent of that from services and software.
- The total U.S. MRM market is projected to grow to 6.5 million units in service by the end of 2012.
- However, the addressable market estimates about 106.6 million units as of 2009, with a lot of room for growth.

As part of MRM, mobile workers are one of the largest segments in the workforce. Any business that fields a sizable mobile workforce faces tough management challenges, including locating and communicating with mobile workers on demand, strengthening dispatching and scheduling capabilities, improving customer quality of experience, and cutting field asset costs and risks. Beyond these challenges, companies are looking to empower their mobile workforces and create additional revenue streams by providing mobile workers with access to back-office applications like enterprise resource planning (ERP) and customer relationship management (CRM) systems.

According to Driscoll, the largest MRM supplier was Qualcomm, with 490,000 units in service by the end of 2009; the second largest was Trimble @Road, which has 250,000 units deployed. In 2011, the author had a meeting with executives from TeloGis, who claim that their TSP services cover 500,000 vehicles. The author led a team and developed a fleet management system called e-Logistics (not NGTP compliant) on top of the general-purpose ^{ez}M2M middleware platform product in 2007 (Figure 2.7). This system has been in operation with China Mobile providing TSP services for nationwide logistics fleet services firms since 2007, currently with 60,000 vehicles from 500+ companies. An M2M service that locates senior people and students was also developed with China Mobile in 2010.

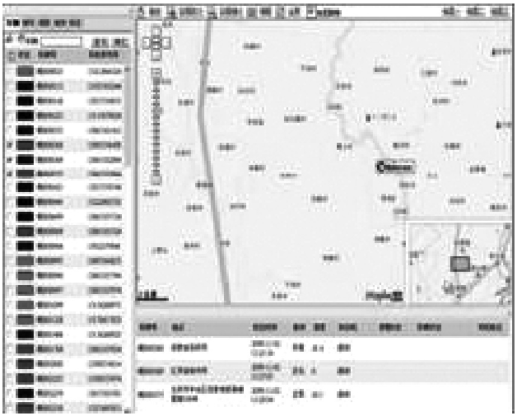

Figure 2.7 e-Logistics user interface.

Telematics and fleet management–based applications can be extended to enable many innovative capabilities:

- Vehicle relationship management has been designed to utilize a vehicle's telematics hardware to provide cost reductions, business efficiencies, and enhanced customer service for automobile manufacturers and their affiliated automobile dealerships.
- Interest has increased across the globe in the benefits of usage-based car insurance, also known as PAYD (Pay as You Drive), which enables vehicle owners to pay reduced car insurance premiums based only on the distances that they drive and the way that they drive.
- Vehicle lifecycle management solution aims to improve customer service, optimize operational processes, lower costs, increase vehicle safety, and improve productivity throughout the automotive design process and supply chain, as well as provides telematics services to vehicle consumers, automotive retailers, car companies, and their suppliers.

The term *intelligent transport systems* (ITS) refers to information and communication technologies (ICT) applied to transport infrastructure and vehicles that improve transport such as transport safety, transport productivity, travel reliability, informed travel choices, social equity, environmental performance, and network operation resilience.

Recent governmental activity in the area of ITS, specifically in the United States, is further motivated by an increasing focus on homeland security. Many of the proposed ITS systems also involve surveillance of the roadways, which is a priority of homeland security. Funding of many systems comes either directly through homeland security organizations or with their approval. Further, ITS can play a role in the rapid mass evacuation of people in urban centers after large casualty events such as a result of a natural disaster or threat. Much of the infrastructure and planning involved with ITS parallels the need for homeland security systems.

According to the U.S. Department of Transportation (DOT) [43], linking vehicles and the transportation infrastructure into an integrated, nationwide system as shown below has been its vision for almost two decades. The VII (vehicle-infrastructure integration) vision, technologies, network, and services are designed to support applications facilitating three major goals: safety, mobility, and e-commerce.

The same vision is shared in Japan, with the goal to reduce the number of vehicle accident fatalities to fewer than 5,000 in 2012, and in the European Union (EU), whose goal was to cut the number of road fatalities by 50 percent in three years. The Next Generation Traffic Management System (UTMS'21) is a new initiative developed by the Universal Traffic Management Society of Japan [44]. In 2003, to realize the original U.S. DOT VII vision, it was determined that the 5.9 GHz dedicated short-range communications (DSRC) would be used by all vehicles by the 2012–2015 time frame. DSRC has been a standard technology used by U.S., EU, and Japanese ITS initiatives (as shown in Figure 2.8). Many other countries are expected to follow.

Figure 2.8 DSRC-based systems.

Apart from DSRC and the aforementioned NGTP and GENIVI, many other alliances and standards organizations are proposing telematics/ITS standards, such as

- Automotive Open System Architecture (AUTOSAR)
- Society of Automotive Engineers (SAE)
- Automotive Multimedia Interface Collaboration (AMI-C)
- 3GPP
- Telecommunications Industry Association (TIA)
- Automatic Terminal Information Service (ATIS)
- Communications for Coordinated Assistance and Response to Emergencies (COMCARE)
- National Emergency Number Association (NENA)
- ISO
- IEEE
- Open Services Gateway Initiative (OSGi)
- ITU
- ESTI

Most of the standards are about the integrated Telematics and ITS systems and applications. Some of the notable ones are OSGi VEG, AUTOSAR, and SAE J2735. Those standards can be employed to work with the DSRC communication standard to realize the VII vision.

2.2.2 Smart Grid and Electric Vehicles

The power grid has evolved into a blended electricity supply and ICT systems as shown in Figure 2.9.

Based on the blending trend, the EPRI (Electric Power Research Institute), an independent nonprofit organization in the United States, proposed the Complex Interactive Networks/Systems Initiative [46], which brought the fundamentals of smart grid together in 1998 as shown in Figure 2.10.

Power SCADA, a technology of IoT characteristics, has long been a stalwart of electric utility operations, becoming increasingly complex as new technologies arrive and new issues emerge on the road to a modern electric smart grid [174]. SCADA/EMS/GMS (energy management system [172], generation management system) supervises, controls, optimizes and

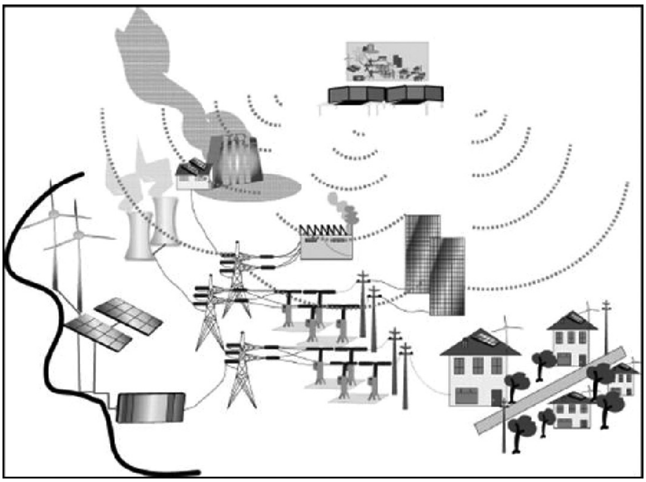

Figure 2.9 The smart grid. (From Melike Erol-Kantarci and Hussein T. Mouftah, "Pervasive Energy Management for the Smart Grid: Towards a Low Carbon Economy," in Hussein T. Shah, Syed Ijlal Ali Ilyas, and Mohammad Mouftah (eds.), *Pervasive Communications Handbook,* Boca Raton, FL: CRC Press, 2011.)

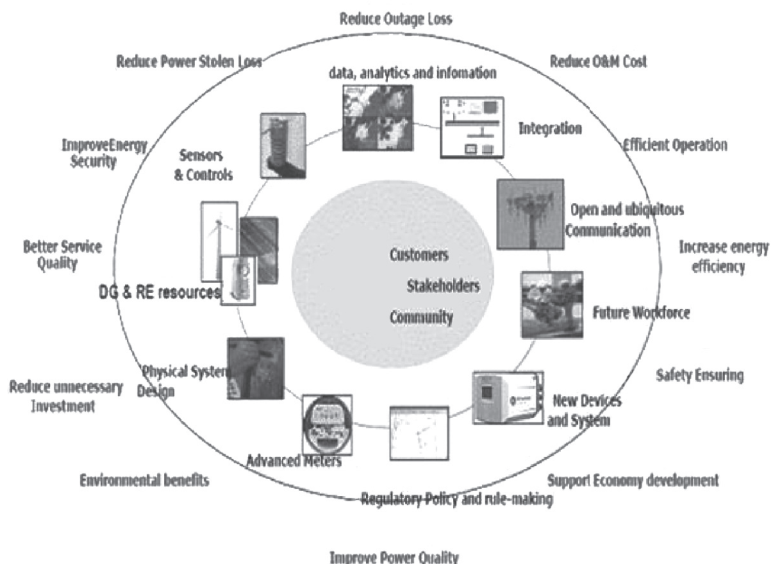

Figure 2.10 Smart grid value chain and stakeholders.

manages generation and transmission systems. SCADA/DMS (distribution management system) performs the same functions for power distribution networks. Both systems enable utilities to collect, store, and analyze data from hundreds of thousands of data points in national or regional networks, perform network modeling, simulate power operation, pinpoint faults, preempt outages, and participate in energy trading markets. These systems are a vital part of modern power networks and are enabling the development of smart grids.

In 2000, EPRI proposed the IntelliGrid initiative. The U.S. Department of Energy (DOE) created the GridWise [193] program during the same time frame. In 2003, the U.S. DOE published its “Grid 2030” report [47]: “‘Grid 2030’ energizes a competitive North American marketplace for electricity. It connects everyone to abundant, affordable, clean, efficient, and reliable electric power anytime, anywhere. It provides the best and most secure electric services available in the world.” In 2005, the European Technology Platform SmartGrids was set up to create a joint vision for the European networks of 2020 and beyond, and the term *smart grid* became widely used since then. The Modern Grid Initiative [175] was created by the National Energy Technology Laboratory for the U.S. DOE in 2007. A NIST (National Institute of Standards and Technology) smart grid interoperability standard [176] specification was proposed in 2010 by Gary Locke, the U.S. secretary of commerce, and Patrick D. Gallagher, director of NIST.

Smart grid technologies have emerged from earlier attempts at controlling, metering, and monitoring. In the 1980s, automatic meter reading was used for monitoring loads from large customers and evolved into the AMI (advanced metering infrastructure) of the 1990s, with meters that could store how electricity was used at different times of the day. Smart meters add continuous communications so that monitoring can be done in real time and can be used as a gateway to demand response-aware devices and "smart sockets" in the home.

Monitoring and synchronization of wide area networks were revolutionized in the early 1990s when the Bonneville Power Administration expanded its smart grid research with prototype sensors that were capable of very rapid analysis of anomalies in electricity quality over very large geographic areas. The culmination of this work was the first operational wide area measurement system (WAMS) in 2000. The IoT technologies and ideologies play an important role in this approach. Other countries are rapidly integrating this technology. For example, China will have a comprehensive national WAMS system when its current five-year economic plan is complete in 2012, with plans to have PMU (phasor measurement unit) sensors at all generators of 300 or more megawatts and all substations of 500 or more kilovolts. In 2009, China announced an aggressive framework for "strong grid" [166] deployment. Compared with that in the United States and in Europe, China's smart grid appears to be more transmission centric [48].

A number of challenges face the power industry that its communications infrastructure is not currently prepared to

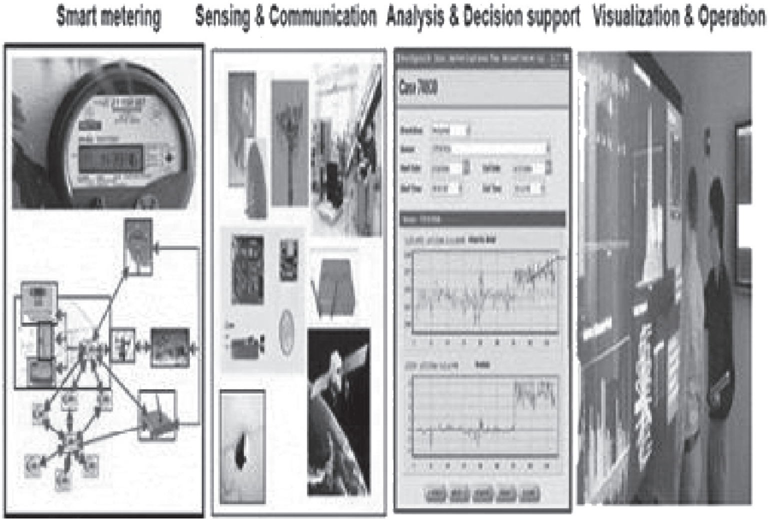

Figure 2.11 Smart grid technologies.

address. A power system making use of an integrated electrical and communications systems architecture (as shown in Figure 2.11) should be as follows:

- Self-healing and adaptive, applying automated applications for protection, fault detection, fault location, sectionalization, and automatic service restoration over wide areas of the service territory
- Interactive with consumers and markets, permitting real-time pricing, energy trading, and load management
- Optimized to make the best use of aging equipment, personnel from multiple organizations, and other resources in a competitive environment
- Predictive, scheduling maintenance ahead of time to prevent rather than just react to emergencies
- Distributed, permitting activities such as generation, metering, load shedding, and others to be easily performed at different locations and by different organizations

- Integrated, merging the previously separate functions of monitoring, control, protection, maintenance, energy management, distribution management, business, and corporate information technology
- Secure, protecting vital infrastructure from cyber or physical attack

Although these functions are performed today by various utilities, there is much variation in the level of implementation, and they are generally not performed on a wide enough scale to address the level of problems faced by the grid today. This scenario is exactly the same as other vertical sectors of the IoT landscape.

The Integrated Energy and Communications System Architecture IntelliGrid Architecture project of Consortium for Electric Infrastructure to Support a Digital Society (CEIDS), Electricity Innovation Institute (E2I), and EPRI has developed an open, standards-based systems architecture for data communications and distributed computing infrastructure that will enable the integration of a wide variety of intelligent electric power system components and transducer devices at a much larger scale and higher levels.

A great many smart grid definitions exist: some functional, some technological, and some benefits oriented. A common element to most definitions is the application of advanced sensor technologies, two-way communications, and distributed processing to the power grid, making data flow and information management central to the smart grid.

The smart grid ecosystem and its drivers and components are described in many research works such as [196,198]. IT giants such as IBM, Cisco, Microsoft, Intel, Oracle, and others have actively participated in many relevant works on smart grids. One of the players of special interest is Google. Google joined the smart grid party by announcing its PowerMeter program in 2009, which aimed to ultimately become an open platform for home energy information. A home energy gadget on the iGoogle home page shows how much energy is being used. The gadget tracks historical data and forecasts future trends. Underneath the PowerMeter gadget is an open systems platform that Google equates to Google Maps, the highly successful geospatial system that has become the foundation for thousands of applications. However, Google shut down the PowerMeter site in 2011 after two years due to lack of users. The reason is not that the PowerMeter services are not needed by users, but rather that it's probably too early in the smart grid development stage, among many other reasons.

Smart grid research will have to consider incorporating renewable energies into the power network and the provisioning of electric vehicles. In a true smart grid, electric cars will not only be able to draw on electricity to run their motors, but they will also be able to do the reverse: send electricity stored in their batteries back into the grid when it is needed. On average, American automobiles get driven for just one hour each day. Most cars are going to have lots of extra battery capacity. Electrifying the entire vehicle fleet would provide more than three times the power generated in the United States. On the other hand, it's important to make sure people are not charging at the very peak time, like late afternoon when the electricity grid is already weighted down by demands like air-conditioning.

Vehicle-to-grid (V2G) describes a system in which plug-in electric vehicles (EVs), such as battery electric vehicles and plug-in hybrid electric vehicles, communicate with the power grid to sell demand response services either by delivering electricity into the grid or by throttling their charging rate. Since most vehicles are parked an average of 95 percent of the time, their batteries could be used to let electricity flow from the car to the power lines and back, with a value to the utilities of up to $4,000 per year per car. V2G is a version of battery-to-grid power applied to vehicles. There are three different versions of the vehicle-to-grid concept:

- A hybrid or fuel cell vehicle, which generates power from storable fuel, uses its generator to produce power for a utility at peak electricity usage times. Here the vehicles serve as a distributed generation system, producing power from conventional fossil fuels or hydrogen.
- A battery-powered or plug-in hybrid vehicle, which uses its excess rechargeable battery capacity to provide power to the electric grid in response to peak load demands. These vehicles can then be recharged during off-peak hours at cheaper rates while helping to absorb excess nighttime generation. Here the vehicles serve as a distributed battery storage system to buffer power.
- A solar vehicle, which uses its excess charging capacity to provide power to the electric grid when the battery is fully charged. Here the vehicle effectively becomes a small renewable energy power station. Such systems have been in use since the 1990s and are routinely used in the case of large vehicles, especially solar-powered boats.

One of the biggest challenges for the mass adoption of electric vehicles by consumers is range anxiety. Having driven traditional cars, where infrastructure for refueling is abundantly established, consumers are still wary of the dead car situation that an EV might pose. Although EV OEMs and battery manufacturers are constantly working to improve battery range, the associated added costs with the increased range pose a threat for mass adoption as well. In the long run, range anxiety might be tempered by producing cost-effective, long-range batteries through constant research and by establishing an adequate public charging smart grid infrastructure. But in the short-term, according to Frost and Sullivan [197], the answer is that OEMs and suppliers should resort to telematics and connected services as a solution to range anxiety

Toyota and Microsoft launched a $12 million venture in 2011 to bring telematics to Toyota's vehicle via the cloud, allowing owners to connect to information services and manage the batteries in their electric vehicles. They will create a global network based on the Windows Azure cloud computing platform, creating a system by which cars like the forthcoming RAV4 EV and plug-in Prius communicate with and draw power from the grid. We'll see it first in the electric and plug-in hybrids Toyota introduced on a limited scale in 2012.

Electric vehicles need to be admired not only for their bodies but also for their brains. According to Pike Research [199], the second wave of EVs and plug-in electric vehicles are likely to be even smarter than the first as automakers are enhancing their telematics features. Toyota is partnering with Microsoft so that its vehicles can communicate with Microsoft's cloud computing technology. Toyota's Media Service division is peering into the home energy management market and will enable its plug-in electric vehicles and their accompanying mobile applications to control electricity consumption in both the car and the home.

In addition to the automakers themselves, telematics companies focusing on EVs abound, including Airbiquity, Automatiks, and Telogis, just to name a few. These companies are extending applications such as green routing to avoid traffic and produce energy efficiency for fleet managers. This increase in the brain power could spell trouble for the makers of electric vehicle charging equipment, who want their devices and not the cars themselves to be the center of smart vehicle charging.

Companies such as GE, Siemens, Ecotality, and Coulomb Technologies see the car–home connection as a great opportunity to expand the value of the equipment and are working on integrating their software with home energy management. They are ahead of the automakers in this regard today, but may not be for long if the major vehicle manufacturers follow Toyota's lead.

The two-way provisioning capabilities of electric vehicles are widely seen as a killer application* to smart grid.

* Killer application or "killer app" is a buzzword that describes a software application that surpasses all of its competitors. (http://www.investopedia.com/terms/k/killerapplication.asp#ixzz22Ogaukm1http://www.investopedia.com/terms/k/killerapplication.asp#axzz22Of3x3Hh)

2.2.3 Smarter Planet and Smart Buildings

Smarter Planet is an IBM initiative mentioned in President Obama's speeches. The initiative seeks to highlight how forward-thinking leaders in business, government, and civil society around the world are capturing the potential of smarter systems to achieve economic growth, near-term efficiency, sustainable development, and societal progress. Many of the challenges the planet faces are concentrated in cities. Cities struggle with traffic congestion, water management, environment protection, public utility management, smart grids, healthcare solutions, building energy efficiency, and rail transportation issues, to name a few. These issues have historically been difficult to manage because of their size and complexity. But with new ways of monitoring, connecting, and analyzing the systems, business, civic, and nongovernmental leaders are developing new ways to address those issues.

According to Forrester, a smart city is one that "uses information and communications technologies to make the critical infrastructure components and services of a city (administration, education, healthcare, public safety, real estate, transportation, utilities, and so on) more aware, interactive and efficient" [274].

Here are some examples for ways that technologies can affect different "systems" required to keep a city up and running, in good health:

- Intelligent sensors that keep tabs on things and places
- Business intelligence and analytics applications that can help slice, dice, and make sense of the data
- Wireless networks and other mobile communications technologies
- Alerts and workflow automation

In building a smart city, ICT has a fundamental role to play. The adoption of hardware, software, and services gives way to the creation of a new, holistic, ICT ecosystem which IDC refers to as “Intelligent X.” IDC defines Intelligent X as a technology ecosystem that integrates the following three areas [45]:

- Smart devices involving M2M/telemetry capabilities
- High-speed ubiquitous communications networks
- Intelligent software and services to process, consolidate, and analyze data in order to transform industry-specific business processes

IDC has outlined seven categories of applications for smarter cities [200]: health; home; sports and leisure; education; transport; buildings; and city services, safety, security, and emergency response. IDC also published a more detailed list of “Intelligent X” core competencies for building a smarter city: city strategic planning, government, networks, devices, verticals, marketing, public relations, and finance.

It is not difficult to find out that the technologies used to build a smarter planet or smarter cities as defined by IDC or Forrester is almost the same as those defined in the Internet of Things in the previous chapter. So the Internet of Things plays an important role in building a smarter planet and smarter cities.

In Cisco’s blueprint for its Smart + Connected Communities initiative [201], connected and sustainable mobility and connected and sustainable energy are two of the three areas that are most important in building a smart city; some important topics related to these have been described in the last two sections. The third area is connected and sustainable buildings, which will be described in greater detail later in this section. The other two areas are connected and sustainable work and sustainable socioeconomics.

Smart buildings are the building blocks of a smart city, which are building blocks of the smarter planet. An intelligent green building is managed by a building management system (BMS) or an interconnected, integrated, and intelligent BMS. All four IoT technologies—SCADA, M2M, RFID, and WSN—can be used in a BMS. A BMS usually controls and monitors the building's mechanical and electrical equipment that integrates the BAS (building automation system), security and alerting system, fire alarming system, closed-circuit TV video surveillance system, access control system, power and lighting system, elevator, broadcasting and background music system, parking system, network and cable TV management system, PMS (property management system), and even office automation system. With the advent of IoT, more systems such as energy efficiency management (power and water usage metering and submetering) are added into BMS.

Although some people have blurred the difference between a BMS and a BAS, we believe that a BAS should be part of an integrated BMS. A BMS usually uses higher level Internet and wireless mesh network protocols as well as open standards such as DeviceNet, ZigBee, EnOcean (energy harvesting technology), SOAP, and XML, and builds on top of a middleware platform such as a three-tiered Java application server for web-based access anywhere, anytime. An open BMS standard named oBIX (open Building Information eXchange) was proposed and maintained by OASIS.

Figure 2.12 is a BMS system product named ezIBS developed by the author's team (ezIBS is the BMS market leader in

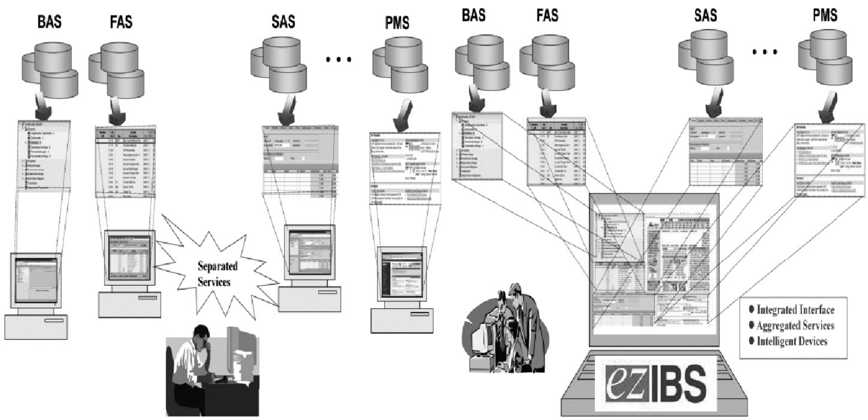

Figure 2.12 Integrated building system.

China and it has been referenced in college textbooks and used as a study system by students [254]). It is a system built on top of a general-purpose three-tier JavaEE middleware platform. With ezIBS, all the component systems (on the left of the figure) in a building are integrated into one interconnected, intelligent system that provides integrated services.

A BMS system is an example of a human machine interface (HMI/SCADA); similar systems include Wonderware and Tridium. BMS evolved from BAS, and BAS evolved from direct digital control and programmable logic controller. Due to the wide adoption of the object linking and embedding for process control standard and historic reasons, most of such systems (such as Wonderware [Intouch, IAS], Rockwell [FTView, RsView], Siemens [WinCC], Axeda [Wizcon], and ArcInformatique [PcVue]) were built using Windows technologies. Newer systems such as Tridium (of Honeywell) and ezIBS are based on open JavaEE middleware technologies.

A BAS is an example of a distributed control system, which, in most cases, covers the HVAC systems of a building, while a BMS is like an information system that does a grand integration of everything in the building (as shown in Figure 2.12). A BAS's core functionality keeps the building climate within a specified range and monitors system performance and device failures. A BAS is usually configured in a hierarchical manner using lower level protocols as CAN-bus, Profibus, BACnet, LonWorks, and Modbus.

ESPC (energy savings performance contract) is an alternative financing mechanism authorized by the U.S. Congress and designed to accelerate investment in cost-effective energy conservation measures in existing federal buildings. ESPCs are regulations created by the Federal Energy Management Program [173] of the U.S. DOE as required by the Energy Policy Act of 1992, which authorizes federal agencies to use private-sector financing to implement energy conservation methods and energy efficiency technologies.

An ESPC is a partnership between a federal agency and an energy service company (ESCO). The ESCO conducts a comprehensive energy audit for the federal facility and identifies improvements to save energy. In consultation with the federal agency, the ESCO designs and constructs a project that meets the agency's needs and arranges the necessary financing. The ESCO guarantees that the improvements will generate energy cost savings sufficient to pay for the project over the term of the contract. ESCOs employ a BEMS (building energy management system) to fulfill ESPCs.

A BEMS is a system that facilitates management and control of building facilities while also realizing energy savings and increasing comfort of building users by making full use of state-of-the-art information technology. A BEMS is similar to a BMS, yet initially focused specifically on energy; while a BMS does have energy management aspects to it, it also includes the monitoring of fire systems and security systems among other building and mechanical controls. BEMS are brought to market by vendors who solely focus on energy management as their means to penetrate customer channels.

According to Pike Research, many BEMS projects are implemented with existing BMS installations. Historically, BMS players such as Honeywell, Johnson Controls, and Siemens have dominated the energy management market for commercial buildings. However, newer, more nimble players, like EnerNOC (convergence) and BuildingIQ (new entrant), are beginning to increase market share and help define a new market.

As a summarization, Figure 2.13 shows the product portfolios of the company the author helped build (the software application systems based on an JavaEE middleware platform) for comprehensive intelligent buildings and smart city applications.

Another IoT application on buildings is the home automation segment. Home automation, also called domotics, is the residential extension of building automation. It is automation of the home, housework, or household activity. Home

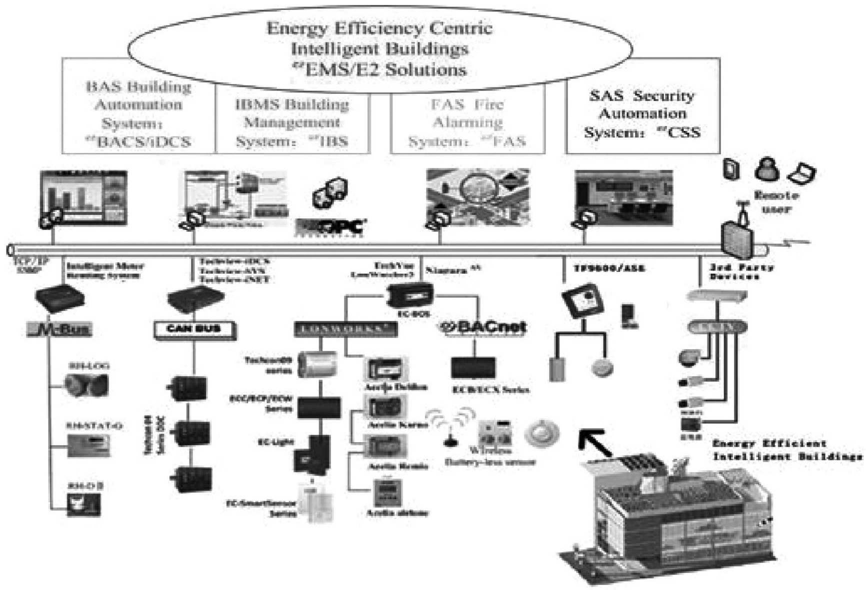

Figure 2.13 IoT applications for buildings.

automation may include centralized control of lighting, HVAC, appliances, and other systems to provide improved convenience, comfort, energy efficiency, and security. Home automation for the elderly and disabled can provide increased quality of life for people who might otherwise require caregivers or institutional care.

2.3 Summary

As an introduction to the widespread, ubiquitous IoT applications, we gave a panoramic view of the IoT application landscape at the beginning of this chapter. We then described three important IoT sectors that IoT technologies and ideologies apply and dominate.

In the next chapter, the four-pillar classification of the Internet of Things will be proposed and outlined. The technologies and applications of each pillar will be described in detail.