Chapter 17
Emerging Business Models for IoT-Based Smart Distribution Systems

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Abstract Recently, Internet of Things (IoT) has been developing in several social areas such as energy, transportation, health, etc., through the physical and virtual connection of objects using the communication and information technologies. In the IoT technology, it is possible to provide different services with high reliability and security levels based on data identification, recording, storing, and processing as well as communication of objects. Meanwhile, traditional power systems are changing towards smart grids to overcome problems regarding the one-way data transmission, energy losses, security and reliability of the system, demand increases, Distributed Generations (DGs) penetration, changing nature of electricity consumers, etc. Moreover, the smart grids use several equipment for monitoring and control of the network. The IoT development as the reliable, accurate, and fast communication and information infrastructure, has led to the belief that the architecture of the future smart distribution networks would be based on this technology. It will make a huge difference in distribution networks due to the use of various equipment such as sensors, actuators, and smart meters. Not only it will cause some technical changes, but also cause structural changes such as stakeholders and their role and relationships, as well as their economic issues. Considering these technical and structural concepts, the existing businesses in distribution networks will be changed. Therefore, new business model canvases should be developed to satisfy the upcoming requirements based on the new business environment. Although several remarkable studies have been conducted to investigate the IoT technology and its applications, its business models have not been developed. This chapter aims to investigate the IoT-based smart distribution grids, and also identify the emerging players and their roles, as well

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as their communications in the new environment. Finally, the appropriate business model canvases will be proposed for the future IoT-based smart distribution grids.

Keywords Internet of things (IoT) · Business model canvas · Smart distribution systems

17.1 Introduction

Nowadays, technological advances and subsequent changes in various aspects of life have been accelerated as a result of information technology. The growing desire for globalization necessitates a better understanding of "change" and the "future" for governments, businesses, organizations, and people. It is clear that choosing the right path, which ultimately leads to maximizing opportunities and minimizing risks and challenges, depends on better understanding the current situation and examining future trends.

In the recent years, different definitions have been provided for the business model, in which the model components have been identified and extracted according to each definition. In general, the business model shows how to gain profit and maintain revenue stream in a period of time. For example, identifying and evaluating a business model alongside a business plan gives the investor and lender a sufficient power to be secure against the uncertainties. By presenting a business model, business plans can be better justified. In this way, issues such as identifying the business model components as well as the types of classifications and patterns available to create a business model, evaluating the business models, and examining the impact of innovation on the structure of business models are important and should be studied.

Nowadays, the increase in electricity demand has caused the power companies to face many problems such as electricity losses, energy shortages, and environmental pollutants [1]. One of the most effective ways to overcome these challenges is to use smart grids, bringing very high profits and efficiency [2]. Smart technologies consisting of subscribers, equipment and communications, modernize distribution networks aiming to supply demand in a reliable manner with less emission footprints. Smart technologies have the potential to bring about fundamental changes in the generation, transmission, distribution, and use of electricity along with economic and environmental benefits that ultimately lead to meeting customer needs and the availability of reliable and sustainable electricity. On the other hand, due to the capabilities of smart grids, the network operator can use the gathered information to make decisions in critical situations and prevent unwanted outages.

In smart grids, IoT has recently emerged as a new communication platform. In fact, smart grids with IoT capabilities make it possible to monitor and control their status. It should be noted that the future smart distribution networks will be based on IoTs that follow their own business models. More precisely, the Internet of Things can be defined by the interaction and cooperation of objects in different environments in order to achieve a common goal by which the physical world becomes a large information system. Therefore, objects can be intelligently identified based on their unique identification and specific internet protocol (IP), and also send and receive data. In this case, they also have access to information collected by other objects. The information will be visible by various smart devices such as mobile phones, computers and tablets. The design of various devices with the ability to communicate wirelessly to track and control via internet and applications, expresses the concept of IoT.

The connection of objects not only changes their nature but also changes their relationships, positions and the way in which the interconnected objects are affected, and creates a new space with new dimensions. This space will bring about structural changes in any area of expertise and thus drastically transform traditional businesses and related models, meaning that the development of new business models will be crucial. The IoT capabilities in sending, receiving and processing data have convinced almost all researchers and experts that this technology will be a dominant and reliable communication platform.

In this chapter, definitions of business models, their components and types of existing models are presented. Further, IoT topics, applications, and key concepts, such as architecture, operating systems, platforms, data processing, storage, and security, are discussed in detail. Finally, related businesses are identified. Overally, identifying and explaining the emergence of new technologies and their effects on the business environment for application in smart distribution networks has been discussed.

17.2 Definition of Business Models

Researchers have considered several approaches to define a business model, including resource-based, activity-oriented, economic, strategy-oriented and networked approaches. It should be noted that a combination of the aforementioned approaches has been considered by many researchers.

(A) Resource-based approach

Some believe that this business model is based on the internal resources of the company and these resources create the capabilities and competencies of an organization. Ref. [3] considers this model as a company's approach for creating and using its resources to provide better value for its customers than competitors.

(B) Activity-based approach

The activity-based business model is based on a set of activities in the form of a process. Betz stated the business model as a summary of how an organization's inputs are converted into value-added outputs. In this category, some researchers have referred to value chain, mainstream production or activities such as marketing [4].

(C) Economic approach

In this approach, the business model is defined based on company's profit and economic justification.

(D) Network approach

Because in today's world, the value creation process takes place across corporate boundaries and as a network, the organization interacts with multiple actors in its business. Ref. [5] considers the business model as the structure and content of transactions between the central company and the trading partners.

(E) Strategy-oriented approach

In this approach, in addition to the internal environment of the company, the competitive environment and strategic options of the organization are emphasized according to the opportunities in the market.

In fact, although the concept of business model has been studied by several researchers over the years, no single definition has been provided. However, based on the literature review, definitions of the business model are provided in Table 17.1.

Organizations need to know more about the factors affecting business models and provide a framework for such models. The benefits of using these models can be mentioned as follows:

1. Determining the exact target markets and identifying the characteristics and needs of customers
2. Providing products and services tailored to the needs of customers to satisfy them
3. Finding suitable communication methods with customers and using appropriate communication channels
4. Creating a balance between the cost and revenue of organization
5. Determining the degree of success in achieving financial and non-financial goals
6. Identifying the main capabilities and competencies of the organization and focusing more on them
7. Determining the structure of the value chain for the company
8. Determining the best business partners.

17.3 The Components of the Business Model

The business models that have been presented so far, from different perspectives and based on their intended goals, have considered different factors. That is why the main framework and a wide variety of components for business models have been proposed. Among these, the most frequent components of business models are as follows:

1. Proposed Value
2. Profitability Model
3. Customer Relationship

Table 17.1 Different definitions of business model from the perspective of researchers in this field

Refs.	Researcher	Business model definition
Timmers [6]	Timmers	An architectural business model for product, service, and information flow includes a description of the various business actors and their rules, a description of the potential benefits to business actors, and a description of revenue sources
Weill and Vitale [7]	Weill and Vitale	The business model introduces a description of the plans and relationships between customers and suppliers that represent the mainstream of production, information, money and key beneficiaries
Amit and Zott [5]	Amit and Zott	Business model is the design of the relationship between the content, structure and governance of the organization that creates value through the use of business opportunities. In fact, the business model is a system of interconnected activities that goes beyond the main environment of the company and shows the relationship between its boundaries and the external environment
Chesbrugh and Rosenbaum [8]	Chesbrugh and Rosenbaum	Business models relate technical capabilities to real economic values by creating innovative zones. In fact, the business model shows how a company creates value by identifying where it is in the value chain
Betz [4]	Betz	Business models are a summary of how an organization's inputs are converted into value-added outputs

(continued)

4. Partner Network
5. Main Activities
6. Market Sections.

Table 17.1 (continued)

Refs.	Researcher	Business model definition
Faber et al. [9]	Faber et al.	The business model of a network of companies aims to create value through the establishment of technology opportunities. These companies need to adapt and balance in technical areas, users, organization and financial requirements
Rappa [10]	Rappa	A business model is a way of doing business that is done by a company for its own survival. In other words, it is the same way of generating income
Afuah [3]	Afuah	A business model is a set that shows what activities a company should do, how and when to use its resources to create surplus value for the customer and gain a good position
Shafer et al. [11]	Shafer et al.	The business model is a picture of the basic logic and strategic choices in order to create and gain value by a company in a network
Nordlund and Teece [12]	Nordlund and Teece	The business model reflects the management assumption about what customers want, how they want it and how the company meets these needs and the amount of payment
Osterwalder and Pigneur [13]	Osterwalder and Pigneur	The business model describes a company's logic in how value is created, presented, and acquired
Demil and Lecocq [14]	Demil and Lecocq	Business model is the method of using activities and resources to ensure the continuity of activity and growth of the company
Meier et al. [15]	Meier et al.	The business model describes the practical model for value creation, revenue generation, and communication between customers and suppliers

(continued)

Table 17.1 (continued)

Refs.	Researcher	Business model definition
Gao et al. [16]	Gao et al.	Business model is a way of showing how partners work together
Lin et al. [17]	Lin et al.	The business model is a set of organizational strategies for creating and managing an organization that includes different items such as revenue model, high level of business processes and alliance
Leitao et al. [18]	Leitao et al.	Business models are formed in response to specific competitive conditions and describe how companies generate revenue according to its value chain and its interaction with suppliers, customers and other partners who have complementary competencies
DaSilva [19]	DaSilva	The business model is the logic of creating value for the company and includes identifying opportunities, gaining competitive advantage and creating more value in the market and dynamic environment

Among the models offered, the Osterwalder and Pigneur model is a general, flexible and practical model for most industries [13]. The nine components of this model reflect how an organization gains profit. In fact, these components cover the four main areas of business: customer, value, infrastructure and financial sustainability. The components of this model are described below and the dimensions of the problem will be clarified by providing an example.

17.3.1 Customer Section

Each organization serves one or more customer sections. In fact, this component defines the different groups of individuals or organizations that the company intends to reach and serve. Customers are the key component of the business model. The organization must intelligently decide which parts it wants to serve or ignore.

Table 17.2 Classification of business model channels

Channels			Channel phases				
Owned by the company	Direct	Web sales	Awareness	Assessment	Purchase	delivery	After sales
Owned by partner	Indirect	Company stores	Increase the level of customer awareness	Help evaluate the value proposition	How to buy products/services	Value delivery	Provide after-sales service

17.3.2 Proposed Value

The organization seeks to solve customer problems and meet their needs through Proposed Value. The Proposed Value component describes a package of products and services that are value to a particular customer. Value is the reason why a company is preferred by the customers. Each Proposed Value consists of a selected package of products or services that meet the needs of a specific section of customers. Some of the Proposed Value are innovative and distinctive. However, some may be similar to current market offers but have additional features and distinctions. Values may be either quantitative, such as price, speed of service, reliability or loss reduction in electricity distribution sector, or qualitative, such as customer experience.

17.3.3 Channels

This component describes how the company communicates and accesses its target customer sections in order to deliver the desired Proposed Value. Distribution and sales communication channels are the interface between a company and its customers. Channels are the point of contact with the customer and play an important role in the customer experience. The business model channel classification is summarized in Table 17.2.

17.3.4 Customer Relationship

The customer relationship component describes the types of relationships that the company establishes with specific sections of customers. These relationships can range from face-to-face communications to automated support services. The customer relationship part of the business model has a profound impact on the overall customer experience.

17.3.5 Revenue Stream

The revenue stream component represents the revenue that the company earns from each customer section. In fact, Proposed Value that are successfully delivered to customers lead to revenue streams. The company should know what value each part of the customer is really willing to pay for. Each revenue stream may have different pricing mechanisms, such as fixed prices, bargaining, auctions, market-based, quantity-based, or return management.

The business model can include two different types of transactional or repeatable revenue streams. Transactional revenue is the result of a single customer payment, and recurring revenue is the result of repeated payments by customers for a Proposed Value.

17.3.6 Key Resources

Every business model needs key resources. These resources enable the company to create and deliver Proposed Value, reach the market, maintain relationships with customer sections, and ultimately obtain revenue. Depending on the business model, different key resources are required. Key resources can be human resources or physical, financial, and spiritual. These resources can be owned or leased by the company or provided by partners.

17.3.7 Key Activities

Every business model requires a number of key activities. These activities are the most important steps that a company must take to have a successful operation. Like key resources, key activities vary depending on the business type.

17.3.8 Key Contributions

Companies choose partners for a variety of reasons, which means partnerships are the basis of many business models. Companies form alliances to optimize the business models, reduce risks, or gain resources. There are four different types of partnerships:

- Strategic alliances between competing companies
- Strategic partnerships and competitors' cooperation
- Joint ventures to create new businesses
- Buyer–supplier relationships to ensure supplies are met.

Table 17.3 Overview of the business model of Osterwalder and Pigneur [13]

Key partners	Key activities	Proposed value	Communication with clients	Customer section
	Key resources		Channels	
Cost structure		Revenue stream		

17.3.9 Cost Structure

The cost structure describes all the costs that the business model components entail. This component describes the most important costs incurred during the implementation of a business model. Creating and delivering value, maintaining customer relationships, and generating revenue result in expenses. After defining key resources, key activities and key contributions, such costs can be easily calculated. Cost structure can have fixed cost characteristics or variable cost. Of course, it is necessary to determine the business model type in terms of cost-oriented or value-oriented. Cost-oriented business models focus on minimizing costs. The goal of this approach is to create and maintain the most agile cost structure possible by maximizing activity automation and extensive outsourcing. But in a value-based structure, the company pays less attention to the cost aspect and its main focus is on value creation. High Proposed Value and dedicated services are the hallmarks of value-driven business models.

The nine components of a business model form the basis for an easy-to-use tool, which its general outline is presented in Table 17.3.

In order to identify the classifications presented in the business model literature, business models based on the classification presented by Osterwalder and Pigneur in the form of five categories of business models including “segregated”, “Follow-up”, “multidimensional platforms”, “Free” and “Open” are discussed [13].

17.4 A Variety of Business Models

17.4.1 Segregated Business Model

According to this view, a company’s businesses fall into three completely different categories: customer relationship businesses, product innovation businesses, and infrastructure businesses. Each one has its own economic, competitive and cultural principles and requirements. It is possible for all three types of businesses to exist together in the same company. But in order to avoid conflicts or adverse interactions, it is ideal to separate them into independent institutions. The economic, competitive and cultural pros and cons of each item are listed in Table 17.4.

Table 17.4 Three main types of business models

	Product innovation	Customer relation management	Infrastructure management
Economy	Early market entry, higher pricing and gaining more market share. Speed is the key factor	High customer acquisition costs, trying to make money from customers. Economic savings due to range are a key factor	High production costs, high production volume. Economic savings from scale are a key factor
Culture	Admissions are low. Many small actors flourish and grow	A few big actors come in	A few big actors come in
Competition	Focus on employees, creative elites	Highly service-oriented, customer-focused	Focus on cost, standardization and efficiency

17.4.2 Follow-Up Business Model

The subject of follow-up business models is the low sales of a large number of items. The focus of this business model type is on offering a large number of products, that are sold from time to time, with a specific and limited audience. The utilization of a follow-up business model requires strong platforms to make products easily accessible to a specific and limited audience and interested buyers. Common examples of this business model are YouTube and Facebook.

17.4.3 Free Business Model

In a free business model, at least a significant portion of the company's customers benefit from a free offer. Customers who pay no money are covered by another part of the business model or customer. Getting something for free has always been an attractive Proposed Value. Demand generated at zero price is more than that provided at other prices. In recent years, the number of free offers, especially on the Internet, has increased significantly. There are several templates that allow you to integrate free products and services with your business model. Some of these free templates, such as ads based on the template discussed in the multidimensional platforms, are well known. The second model is the Freemium (free and premium) model, which provides basic and introductory services for free and charges for additional services. This pattern has become increasingly popular with the increasing digitization of products and services offered through the web. The third model is the prey and hunting model, in which a free or low-cost offer is offered to encourage customers to repeat the purchase.

17.4.4 Open Business Model

Companies can use open business models to create and acquire value through systematic partnerships with partners outside the organization. Creating and gaining value in this way is possible in two ways:

- Exploitation of external ideas within the company during the "Outside-to-Inside" process.

Outside-to-Inside innovation occurs when an organization incorporates ideas, technology, and intellectual property outside the organization into its development and commercialization processes. Starting companies with strong brands, distribution channels and customer relationships are well-suited to the open Outside-to-Inside business model. They can dramatically improve the quality of current customer relationships by relying on external sources of innovation. On the other hand, acquiring innovation from external sources requires the financial sources. Therefore, the company must increase the internal productivity of research and development by reducing the time required to supply the market.

- Presenting ideas or unused assets inside the company to outside during the "Inside-to-Outside" process

In Inside-to-Outside innovation, organizations transfer or sell ownership of their unused technologies and assets. Some R&D outputs that remain unused within the company for strategic or operational reasons may be of great value to organizations in other industries. Usually organizations with significant domestic R&D operations have a lot of unused knowledge, technology and intellectual property. These companies do not use some of their assets to focus on their core business, and as a result these assets, which can be valuable for other applications, remain unused. Such businesses are good candidates for an open Inside-to-Outside business model.

17.5 IoT Ecosystems

17.5.1 The Concept of the Internet of Things and Its Application

The International Telecommunication Union defines IoT as follows: There is a connection for anyone or anything at any time and place. Figure 17.1 shows the different dimensions of IoT [20].

The information flow required for IoT can be discussed in four steps, which are:

1. Data collection
2. Transfer of selected data through communication networks
3. Data Evaluation and estimation

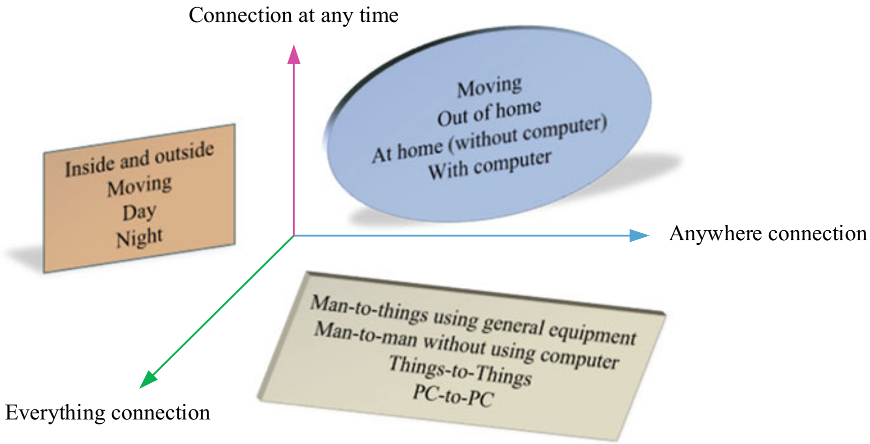

Fig. 17.1 The concept of IoT

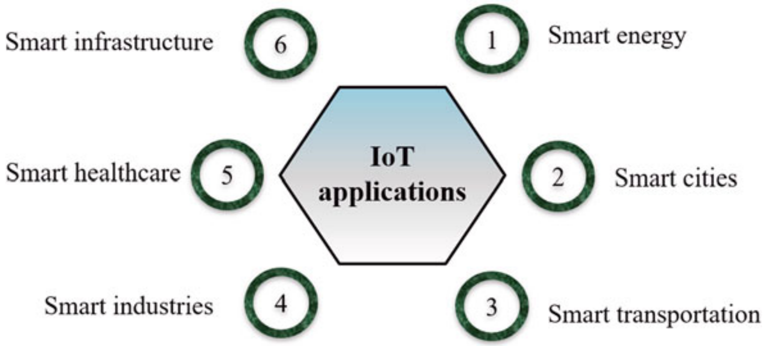

Fig. 17.2 The IoT applications [23]

4. Response to the created needs.

IoT applications are very broad and not only include the medical, health and transportation fields, but also encompass smartness in various areas. The use of IoT in smartness is very diverse and can appear in different industries. Some researchers believe that the application areas for IoT are very wide, as shown in Fig. 17.2. [21, 22] (Fig. 17.3).

17.5.2 Different Types of IoT

The three main types of IoT are as follows [20]:

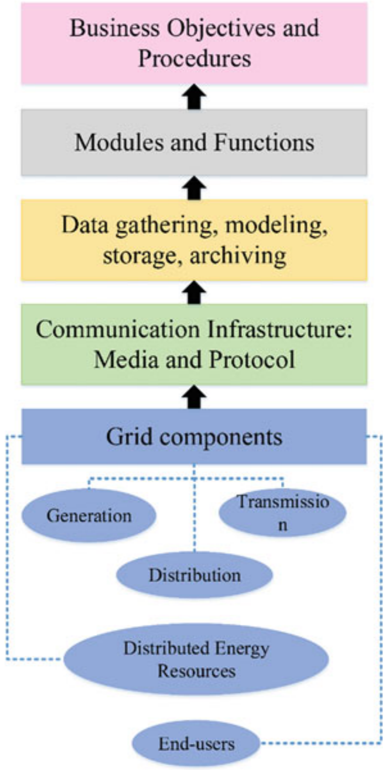

Fig. 17.3 Smart grid architecture [24]

- Industrial IoT: It means the application of this technology in industrial fields and its use as an smart industrial network.
- IoT for Consumers: Unlike industrial environments, the consumer IoT does not need to be real-time. At the same time, the certainty of the answer is not important and its structure is based on the interaction of the device with humans. In this type of IoT, the connection is usually client/server and the data is in a continuous flow with high volume.
- Machine-to-machine (M2M) connection: In M2M systems, the devices are connected to each other one by one. Practically, in this type devivices do not exchange a lot of data and consequently there is no place to store the data.

17.5.3 IoT Architectures

The wide applications of IoT has a tremendous impact on human life. For this purpose, IoT needs a coherent and coordinated structure and architecture. It should be mentioned that, from the viewpoint of researchers, experts, and large corporations, IoT architecture and infrastructure are more important than its implication.

IoT helps to develop new businesses that are driven by technological solutions. Putting aside some business considerations, it is obvious that current solutions cannot meet all the IoT needs. In the field of communication and management, existing devices do not have the necessary functionality for IoT. Lack of coordination and compatibility between existing governance models creates problems in the field of privacy, security of individuals and companies, and creates legal consequences in terms of legal vacuum. But if there is a coherent architecture, it can provide a solution for existing designs. In fact, IoT has the concept of providing services and creating communication levels and is expected to be applicable in various fields. As a result, an IoT reference model is needed at first to implement such a view (A model that can create a common understanding and language between all devices equipped with IoT). The most populare architectures are:

1. IoT-A architecture
2. MGC[1] architecture
3. Five-layer SOA and compose architectures
4. WOA[2] architecture
5. Architecture proposed by ITU
6. Architecture proposed by Cisco [24]
7. Four-layer SOA architecture [25]
8. Ericsson proposed architecture
9. Architecture proposed by Harbinger
10. WSO2 architecture
11. Korean architecture [26]
12. CCSA[3] architecture.

17.5.4 Operating Systems on IoT

In general, IoT devices are divided into two categories in terms of efficiency and capability. The first category is unlimited devices that can run normal operating systems such as Linux and Windows (High-end) such as RaspberryPi due to sufficient resources and appropriate specifications. The second category include devices with limitations in Processing power (limited amount of RAM and ROM) and limited power, can not run normal operating systems (Low-end) such as Arduino, Econota, Zolertia.

[1] Embedded Devices Gateways Cloud.

[2] Web Oriented Architecture.

[3] China Communications Standards Association.

17.5.5 Data Storage

An important part of IoT is data processing when needed (not always). For this possible processing, the data must be stored somewhere. Due to conditions such as the existence of various data from different sources, huge data volumes, low-level data with poor semantic relevance and inaccurate data, measures should be taken to store them. Due to the above issues, various data modules have been developed and used in IoT. In general, IoT data modules include the following [27]:

- Data collection and integration module
- Data storage module
- Data management module
- Data processing module
- Data mining module
- Application optimization module.

17.5.6 IoT Platform

In addition to nodes and networks of IoT, data needs to be processed before it reaches the user or another node. Thus, an interface between IoT elements is required to perform these tasks. This interface is called a platform. In general, there is no clear definition for a platform. The IoT platform is divided into two parts: the software and the hardware platforms. The hardware platform includes the hardware part of the nodes and related items. The data received from the nodes is transmitted by the network to the software platform. This data is transmitted to the user or another node after processing by the software platform. Usually wherever the term IoT platform is mentioned, it mostly refers to a software platform. In fact, anything between two nodes or nodes with the user that is not performed by neither the node nor the user, is the responsibility of the IoT software platform. Therefore, the other layers are part of the software platform.

17.5.7 IoT Data Processing

One of the issues that needs to be addressed in some IoT applications is big data processing or IoT data processing. In the future, a large number of devices, including High-End and Low-End, will connect to the Internet and generate big data. This data can be categorized into three dimensions: volume, variety and velocity. In applications such as smart city control, health, etc., that it is necessary to extract results from data and allowed to do so in terms of privacy, the issue of dealing with big data and processing it to get results is important.

17.5.8 Internet Network

One of the most important parts of IoT is the connection of objects with an independent identity to the Internet. To do this, solutions should be created to connect all devices, both Low-End and High-End. The next issue is the number of devices connected to the Internet. As the number of devices connected to the Internet is increasing, this imposes a large volume of data transmismitted via the Internet. Hence, the infrastructure network should be able to ensure the secure data transfer. Data received from some IoT devices, such as sensors, should be processed if necessary. This requires servers with special capabilities to be able to process data volumes quickly and, if necessary, as soon as data is entered. Thus, servers should use methods such as distributing their various components and connecting these components over the network.

According to the explanations, the network used in IoT can be divided into the following three parts [28]:

- Network of nodes connecting to the internet or sensing network
- Internet infrastructure network or delivery network
- The network used between the components of the data processing system or analytics network.

17.5.9 IoT Security

One of the main problems in IoT security is malicious activities or cyber attacks. In fact, many reasons including the limitations of objects used in IoT (such as the lack of enough space for saving data, their programmabilities, etc.), the presence of numerous sensors, operators, and physically accessible objects, the wireless connections of objects in IoT, and the openness of the system, make IoT-based systems the target of security attacks. Backdoors that are entered into the system by vendors and through object updates are one of the most important concerns in IoT. Identifying and naming things is also a crucial issue. Moreover, the use of wireless sensor networks in IoT can also cause security problems. The important challenges and main research areas in the field of IoT security are listed below:

- Identifing and locating objects on IoT
- Authentication and access permission
- Privacy
- Existence of trust
- Security protocols and lightweight encryption systems
- Software vulnerabilities
- Vulnerability to malware.

17.5.10 IoT Technologies

In IoT, various technologies have been proposed so far in order to communicate between objects and the Internet. The separation of IoT technologies seems difficult due to the interdependence and complexity of technologies and tools. However, fog and 5G computing technology can be mentioned as the new technologies of IoT. After that, we can refer to fiber optic and satellite technologies that are used for data transfering. Communication technologies are divided into short and long-range communications, sensor-related technologies, location technologies, detection technologies, wireless sensor network technologies, and finally virtualization technologies as complementary to IoT.

17.5.11 Suggested IoT Ecosystems

The Internet of Things, known as the new industrial revolution, has also transformed the interactions between governments and the world around them with the virtual and technological worlds due to changes in people live, work, entertain and travel patterns. The interaction between various elements and objects, resulting from IoT, lead to complex relationships with many actors and a concept called ecosystem that can be adopted in complex situations. Suggested ecosystems for IoT are as follows:

- IDC proposed ecosystem
- CompTIA proposed ecosystem
- BI Intelligence proposed ecosystem
- IEEE and EricssonProposed Ecosystem [29, 30]
- Ecosystem from IoT Tree of Life proposed by ARM [31]
- Postscapes proposed ecosystem.

17.6 IoT-Based Smart Distribution Grid

The Internet of Things is expanding in all areas of society, including energy, transportation, manufacturing, health, etc., through the physical and virtual connection of objects and the use of existing and evolving communication and information technologies. The existence and development of IoT technology as a safe, fast and more accurate platform compared to other technologies, has strengthened this belief and opened a variety of research and engineering paths for researchers and engineers.

17.6.1 Introducing Smart Grid

As the energy demand increased, power companies faced many problems, including electricity losses, energy shortages, and environmental pollutants [1]. Power distribution systems should be smarter because of major reasons such as increasing demand for electricity, expanding the use of modern communication and information technologies in the electricity industry, inefficiency of network capacity development, restructuring in the electricity industry, reducing dependence on fossil energies, environmental issues, penetration of renewable energy sources and energy storages [32].

Since there is still no standard and precise definition of smart grid, smart grid is typically defined as a system that allows power companies to remotely control and command grid equipment in a real or near real time. In smart grid, by establishing communication between grid components and consumers with software platform, in addition to two-way data transfer from the grid to the consumer and vice versa, energy flow is also transferred bi-directionally between the consumer and the grid [33]. The US Department of Energy has introduced the following features for smart grids:

- Ability to actively participate in consumers
- Ability to adapt the grid to a variety of products and storage of electrical energy
- Providing the necessary power quality for different levels of consumption
- Applied optimization of equipment and efficient operation
- Ability to troubleshoot and healing, and stability against possible damage
- Telecommunication and cyber security [33].

17.6.2 Smart Grid Architecture

The Smart Grid Architecture Model (SGAM) is used to manage complexities in the smart grid. This architecture includes domains, areas, and layers of collaboration. Each part of this architecture is explained as follows [34].

Domains consider the energy conversion chain and include the following.

(1) Generation (both renewable and non-renewable generation)
(2) Transmission (infrastructure and organizations for long-distance power transmission)
(3) Distribution (infrastructure and organizations for electricity distribution to customers)
(4) Distributed Energy Resources connected to the distribution networks
(5) Customer premise (producer and final consumer of electricity, including industrial, commercial, residential facilities, and production in the form of photovoltaics, storage in electric vehicles, batteries, and small turbines).

The hierarchy of power system management and control in smart grid architecture varies with zones, including the following:

1. Process (physicals and chemical transfer of energy and equipment required)
2. Field (equipment for protection, control, and monitoring of power system processes)
3. Station (geographical aggregation level for equipment area, data aggregation)
4. Operations (management and control operations of the power system in the relevant area)
5. Economic organizations (Enterprise) (processes and infrastructure, for example, asset management, staff training, customer relationship management, billing)
6. Market (energy, trade, wholesale, retail).

Finally, layers of collaboration are defined in the smart grid architecture model as a major requirement for distributed systems. Layers of collaboration, encompasses various sections such as business (Business View on Smart grid information Exchange), functions (use of functions and services independent of their physical implementation), information (object information or data model for interoperability), communications (protocol for the transfer of information between equipment) and physical components (power system equipment, protection and control devices, control center infrastructure and network) [34].

17.6.3 IoT-Based Smart Distribution Grid

The Internet of Things is a new concept in information and communication technology, in which objects and equipment are connected to the Internet and can be controlled and managed by applications on smartphones and computers. Assuming that the objects and equipment mentioned are the objects and equipment of the distribution grid, the IoT-based smart distribution grid will emerge as the most modern smart distribution grid [20].

17.6.4 IoT-Based Smart Grid Architectures

Existing architectures for IoT-based smart grids include:

(1) Three-layer architecture: the IoT-based three-layer smart grid architecture is based on IoT features. This architecture consists of three layers of perception, network, and application.

(2) Four-layer architecture: a four-layer architecture for IoT-based smart grids is based on smart grid information features and communication systems. This architecture consists of terminal layers, field network layer, telecommunication layer, and main central system layer.

(3) IoT-based smart grid architecture for energy efficiency: improving energy efficiency in buildings is an essential aspect of smart grids. Smart energy is an important research topic in IoT. The four objectives of implementing

this system include energy-saving, mobile control and monitoring, automatic location-based control, and the use of a cloud computing platform for data storage and computing.

(4) Web-based architecture for IoT-based smart grids: One of the proposed architectures for IoT-based smart grid is web-enabled smart grid architecture. In the Web of Things, the web browser acts as an interface to the services required by IoT.

(5) The latest measurement architecture for IoT-based smart grids: The latest smart gauge meter is the closest to home, that is, the part that interacts with consumers. This architecture has three main components: a network of sensors and operators, server, and user interface.

17.6.5 IoT-Based Smart Grid Communication Infrastructure

The communication infrastructures of smart grid include Home Area Network (HAN), Neighborhood Area Network (NAN), and Wide Area Network (WAN). Figure 17.4 shows the smart grids based on the infrastructure of these three networks [35].

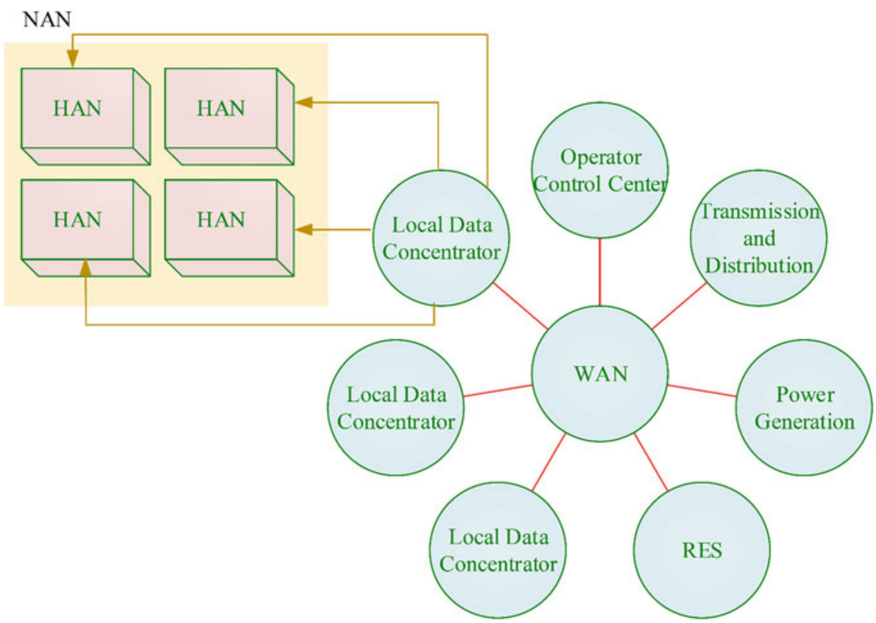

Fig. 17.4 Smart grid communication infrastructure [35]

17.6.6 IoT Applications in Power System Distribution

In the following, the applications of IoT in the smart distribution network are discussed. These applications are new specifications and features added to the traditional distribution network which build the IoT-based smart distribution network.

(1) Management of electric vehicles

Electric vehicles can be used as energy storages in the IoT-based smart distribution network. These devices provide environmentally friendly transportation by reducing carbon dioxide emissions. Efficient energy transfer between electric vehicles and smart grids requires exchanging information between electric vehicles, charging stations, and infrastructure.

(2) Integrated Distributed Energy Resources (DERs)

With the expansion of the installation and operation of renewable energy generators such as photovoltaic cells and wind turbines, these resources are gradually being integrated with the power grid. Renewable energy production centers are distributed throughout the power grid, and their production depends on the location and climatic conditions. This poses challenges to the predictability and reliability of production resources. The Internet of Things predicts the availability of energy in the near future with the help of wireless sensors and by collecting real-time weather information from sensors. The Kalman filter is used to estimate conditions in IoT-based smart grids. In this case, IoT is used to sense, estimate, control, and aggregate energy resources [36].

(3) Smart monitoring of electricity distribution network

Monitoring, Protection, and Distributed control Systems have made it possible to access power grid information. Monitoring systems can be based on IoT. In the monitoring system, the Phasor Measuring Device (PMU) is used as a network information acquisition device, and the control center can automatically and manually control and protect the network with network distributed information by analyzing the information received from this device.

(4) IoT-based power system theft detection

Electricity theft is a major problem in the grid worldwide, which is illegal and should be banned. Electricity theft means using electricity without any contract with the supplier. In this method, in order to eliminate power theft, its location is determined so that the necessary actions can be taken against the violators.

(5) Smart distribution post

Due to the increase in distributed generation, there is a need to increase component information in medium voltage (MV) and low voltage (LV) networks. Several MV/LV smart posts have been designed to manage fluctuations while maintaining network quality and reliability. These models are built to overcome specific problems of distribution networks such as voltage harmonics, resonance, and peak load reduction.

(6) Smart Street Lighting

Despite the countless brightness of passage, smart systems can affect sensors and identify the presence of individuals or vehicles to a large extent in reducing energy consumption.

(7) Energy Storage

Renewable energies play an effective role in supplying energy due to efficiency and cost-effectiveness, and their use is increasing. Despite this process, maintaining the balance between supply and demand is a constant challenge for renewable energy providers, and the variable nature of this type of energy is an obstacle when aggregated with the network. Renewable energy sources are not able to compete with fossil fuels in reliability due to periodic production. To increase the stability of power supply from renewable energies, providers of this type of energy are equipped with Internet-based energy storage systems. Additional energy obtained from renewable sources such as solar, is stored per day. This stored energy is used whenever the demand is greater than generation or the frequency need to be adjusted. Among these systems, the Solo Energy and BYD storage system can be referred.

(8) Demand Side Management

Demand Side Management (DSM) represents the interface between energy departments and energy consumer equipment with the aim of reducing the demand peak in the network, minimizing casualties, and increasing the use of energy storage. Internet-based management platforms (with smart energy management function at point consumption) are necessary for the successful implementation of DSM applications. In demand management, there are various options such as discounts, stimulus and motivation factors to save costs.

(9) Interactive effects of AMI

AMI, as an infrastructure platform, contains five main station sections, a communication channel, data collection terminal, power measurement, and auxiliary equipment. This system provides a smart architecture with an automated two-way flow between smart electrical measurements, other terminal equipment, and power companies. This system can be used to support real-time acquisition, measure and analyze the electrical conditions of users as well as sending data and subjects through the communication layer. Users can be informed of their real-time usage of electricity, and using the reference price, select a wise choice of energy consumption. Meanwhile, power network companies can analyze the status of electricity and provide timely and accurate data for managerial decision making and investment analysis. This important technology is a modern marketing backup and a vital part of the smart grid.

(10) Using IoT in wind turbines and solar cells

(A) Using IoT and mainly through the Wireless Sensor Network (WSN), wind data can be collected, and the output variation can be predicted in real-time as well. Through a wireless sensor network, the monitoring center records real-time wind turbine information and sends real-time collected data to the prediction server. The result from the predictive server processing is transmitted to the wind power station and can also be transferred to the timetable server. The timing server welcomes the prediction results at the distributor station.

(B) With the development of IoT, sensors can be installed on solar panels so that benefits such as real-time monitoring on status, real-time reforms and predict analysis, are achievable. An Internet sensor can control specific panel parameters such as energy output, temperature, tilt angle, and the original direction. These details provide the ability to monitor and modify panels to solar farms. Through real-time monitoring, the solar farm manager can see and resolve the problem in the panels with the aim of retaining the efficiency.

(11) Asset Management

Nowadays, network operators have limited access to network assets, because only access to part of key assets (such as active power, reactive power, voltages and currents). This results in limiting operators in full understanding of conditions, analyzing problems and prediction of situation [37]. The electricity network assets are wide-scale, therefore, it needs abundant information to be managed. With this in mind, internet technology can be used widely in asset management.

(12) Monitor Transformer Parameters

The architecture of the Master Secondary Sub-station (MSS) smart grid is shown in the IoT platform in Fig. 17.5. This system shows the monitoring of the Internet platform for the transformer. The main idea of this plan is to collect transformer information from the post (Fig. 17.6).

(13) SCADA-based IoT integration with fog for Distribution Automation

The Distribution Automation (DA) is part of the smart grid that refers to the functional automation of the entire distribution system and is in fact a combination of SCADA and information-related information programs. Distribution Automation can combine local automation, remote control equipment, and central decision making with a flexible and cost-effective operating architecture to maintain the integrity of the distribution system characteristics of the power distribution system. Application of sensor in distribution automation includes:

- Smart measurement for consumer monitoring and control
- Line sensors for monitoring voltage resources and flow lines
- Smart electronic equipment for monitoring temperature, load, voltage, flow, and power sources.

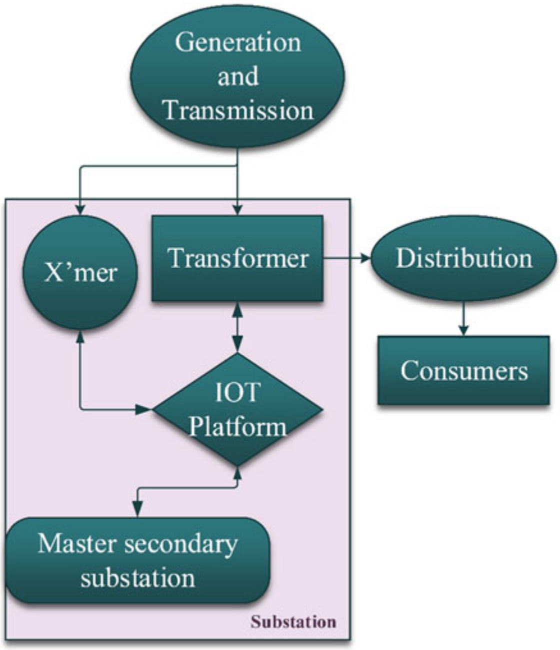

Fig. 17.5 Proposed MSS system architecture based on IoT in smart grids [38]

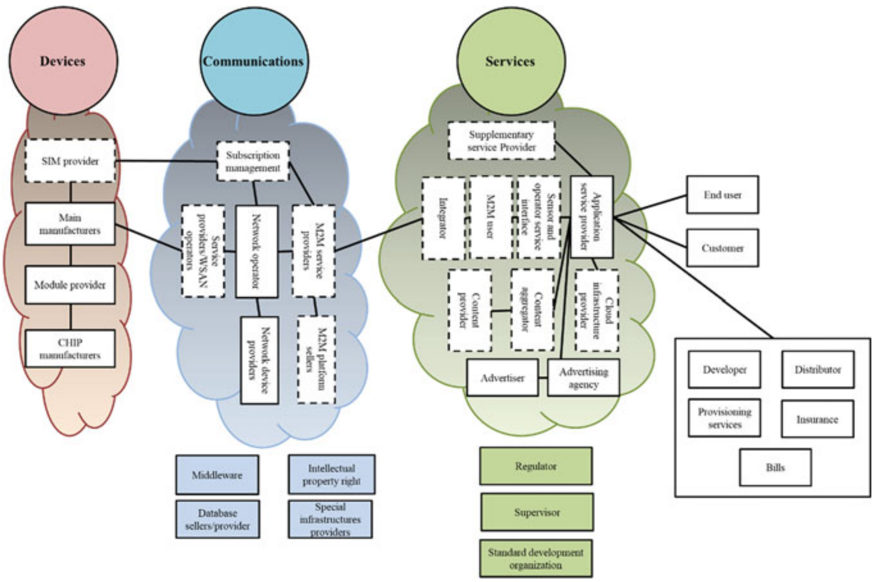

Fig. 17.6 Maps in IoT ecosystem [39]

(14) Prosumers

In traditional power systems, the actors can be referred to as either generators or consumers. Today, renewable energy resources, storage and Demand Response (DR) allow the consumer to generate and store energy. This leads to an emerging new type of customers known as prosumers. In fact, in smart grids, the consumer, generator, and storage are integrated, and the preconditions for microgrid formation are provided [39]. Prosumers not only consume energy but also share excess energy generated by renewable energy resources with the grid or other consumers.

17.7 New Businesses in IoT-Based Distribution Networks

Structurally, business ecosystems can generally have a star structure with a hub or a flat mesh structure. The star structure is the usual model in the United States of America. In this model, it is assumed that the ecosystem communicate with a large number of small suppliers through a central hub. Moreover, the flat model of the business ecosystem that is common in Europe is made up of a large number of small and medium enterprises, but at the same time able to match to the largest one.

A business ecosystem includes social interactions of companies and individuals with their social and economic environment, in which companies are usually competed and cooperated with their main assets (related to the physical and the virtual world of the Internet). The main assets may be hardware and software products, platforms, or standards. The focus of standards should be on connected devices, their communications, software services made on these connections or services required to provide them, warranty, as well as billing for the services.

Generally, IoT consists of three components of devices, communications, and services, which are not necessarily homogeneous, but work together with the ultimate aim of IoT. In terms of role and responsibility, in addition to the abovementioned cases, the rols related to the life cycle of the product or service, including development, distribution, supply, guarantee, and billing, should not be avoided. Other essential functions include legislation, supervision, standardization, and other institutions that directly or indirectly affect IoT [40].

17.7.1 The Conceptual Model of the Smart Grid and Its Components

The conceptual model of the smart grid is in fact the basis of the analysis of the features, use, behavior, relationships, requirements and smart grid standards. This model does not only show the ultimate architecture of the smart grid, but is also a tool for describing that architecture. The smart grid conceptual model provides

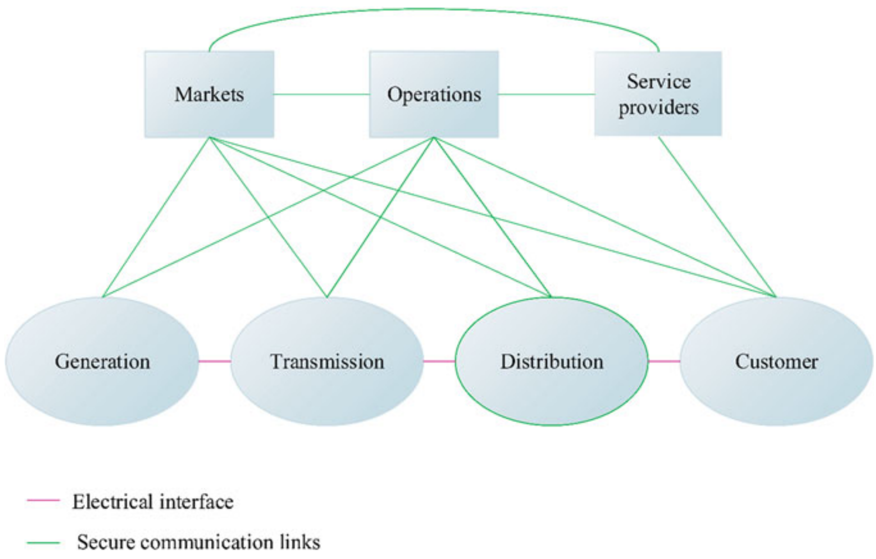

Fig. 17.7 High-level smart grid conceptual model [41]

ground for mutual analysis to develop smart grid architecture. The smart gird model is depicted in Fig. 17.7. Here, components are displayed as clouds.

The conceptual model has several components, each of which includes many applications and actors connected by the associations, with many interfaces. Actors may be devices, computer systems, software programs, or their owner organizations. The ability to decide and exchange information between actors is possible through interfaces. The tasks performed by actors inside the components forms the applications, some of them are carried out by a single actor and others in collaboration with several actors. In general, actors have similar targets. Telecommunication in a similar component may have the same characteristics and requirements. Components may also include elements of other sectors. Relationships are logical communication between actors, which creates two-way communication. At each end, there is a continuity of an interface for an actor. The interface shows electrical or telecommunication connections. In Fig. 17.7, electric relationship and telecommunication interfaces are shown with red and green lines, respectively. Each of these interfaces may be two-way. Telecommunication interfaces indicate the exchange of information between two components and the actors inside them, indicating physical connections. Still, they show logical connections in the information network of different components of the smart grid.

The following table has described the components of the conceptual model of smart grids (Table 17.5).

It is important to note that the smart grid model is not limited to a specific component, application, or specific sample. The use of the term smart grid in some cases refers only to automation distribution, while in other cases, it stands for advanced

Table 17.5 Components in the smart grid conceptual model [41]

Components	Actors
Customers	They are the final consumers of electricity. Customers may also generate, store and manage energy consumption. There are generally four types of customers in the smart grid: home, commercial, residential and industrial
Market	Operators and participants are in the electricity market
Service providers	Organizations that provide services to customers and offices
Operations	The managers of the electricity chain
Mass production	Power generators are large-scale producers. They may also store energy for later distribution
Transmission	Transmits mass-generated electricity over long distances. It can also store and generate electricity
Distribution	Distributors of electricity to and from customers. It can also store and generate electricity

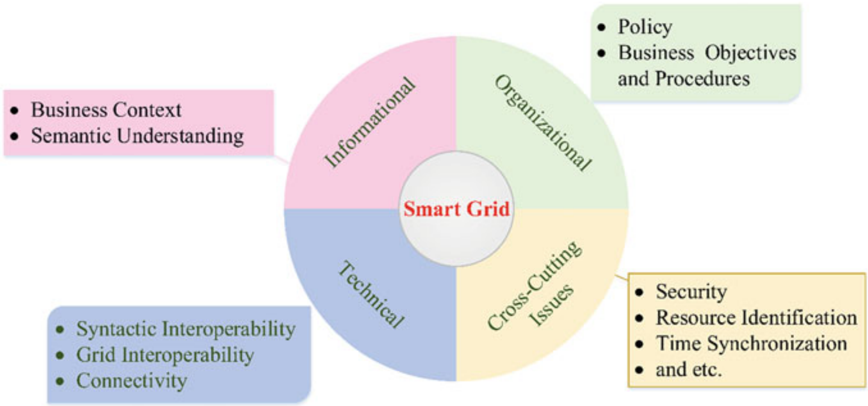

Fig. 17.8 Smart grid conceptual model and GWAC collaboration[4] framework [41]

measurement. In the conceptual model of the smart grid, it is assumed that network smartness includes a wide range of applications.

In general, the smart grid and its components, can be investigated through four dimensions including organizational, informational, technical, and mutual requirements aspects. These dimensions, as well as the energy and information flows are demonstrated in Fig. 17.8. However, gridwise architecture, the layers of this framework can be interpreted as a subset of actors, components and interfaces in the model.

[4] Grid Wise Architecture Council.

17.7.2 Identifying Businesses Related to IoT-Based Smart Distribution Network

To simplify the extraction of IoT-based smart grid business models, IoT business companies are divided into five general categories: Device supply companies, Communication companies, Service providers, Product/service life cycle companies, Supervision companies, and others.

17.7.3 Business Model Canvases on IoT-Based Smart Distribution Network

In the IoT-based smart distribution network, smart distribution business and IoT are merged. In fact, the variety and volume of activities in the smart grid, especially the distribution sector, are such that internet service providers (ISPs) can purely focus on works and activities in this sector. Therefore, there exist sixteen main business model canvases in the IoT-based distribution networks, listed below in accordance with Table 17.6.

1. The business model canvas of IoT device supply companies
2. The business model canvas of communication companies
3. The business model canvas of service providers

Table 17.6 IoT-based smart distribution network businesses

		Prosumers and distributed generations	Market operations
IoT-based smart distribution network businesses	Smart distribution network businesses	Aggregation	Retail
		Installation and maintenance of the network and the customer facilities	Financial services
		Storages	Network operation
		Design, manufacture, and equipment supply	Education, technology research, and human resources
	IoT businesses	Device supply companies	Communication companies
		Service providers	Companies providing product/service life cycle
		Supervision companies	Auxiliary map

4. The business model canvas of product/ services life cycle companies
5. The business model canvas of Supervision companies
6. The business model canvas of IoT auxiliary companies
7. Prosumers business model canvas and distributed generation resources
8. Business model canvas of market-related companies
9. Aggregator business model canvas
10. Retail business model canvas
11. The business model canvas related companies with installation, smart distribution network maintenance
12. The financial business model canvas
13. The storage business model canvas
14. Network operating business model canvas
15. The business model canvas of companies designing, manufacturing, and supplying equipment
16. Business model canvas of companies active in the field of education, technology research, and human resources.

17.7.4 IoT-Based Smart Distribution Network Problems and Challenges

Given that the IoT-based smart grid is an emerging technology and has not yet reached puberty, there are significant challenges ahead. Therefore, it is necessary to pay special attention to these challenges so that this technology can provide fine services to its consumers. In the following, the challenges in this area are discussed [36].

(1) Different working conditions and devices with limited capabilities

IoT-based smart grid systems are subject to different operating conditions. Therefore, providing the requirements for reliability, accessibility, compatibility with hybrid communication technologies and signal coverage in adverse environmental conditions is of particular importance. IoT solutions for self-improvement and self-organization should also be considered. For example, when a set of IoT devices have difficulty communicating, the alternative path should be chosen by the IoT self-improvement feature so that the reliability of the smart grid is not compromised.

(2) Energy Consumption

In IoT-based smart grids, IoT terminals and sensors are supported by batteries in many applications. Therefore, energy consumption of this equipment is a serious problem for the realization of IoT applications in the smart grid. Consequently, it is necessary to design suitable energy storage sources for IoT equipment and power generation equipment and energy conversion. Currently, the new generation of batteries can last more than ten; however, there are still limitations in the energy consumption of this equipment.

(3) Safety against severe environmental conditions

IoT devices are exposed to extreme electromagnetic conditions in some smart grid applications. Therefore, the protection of this equipment and the use of new technologies with the capabilities of resistance to dust, water, electromagnetic waves, vibration, and high and low temperatures in the construction of IoT devices and their chips should be considered for longer life.

(4) Communication Networks

Throughout the communication paths, from the equipment to the local network, then to the gateways, then to the central server, and finally to the cloud, different communication protocols are used every time. Furthermore, the reliability and speed of communication are of a lot of importance. Therefore, despite compression techniques and various networks, IoT-based smart grid systems should be provided with comprehensive network support.

(5) Data Fusion

IoT equipment In IoT-based smart grids, resources and storage, bandwidth, processing, and battery capacity are limited. Therefore, IoT devices cannot transfer all the data to the gateway for data collection because it requires a lot of bandwidth and energy consumption. In general, the only optimal solution is to use the data synthesis process to filter and collect only helpful information from multiple IoT devices. This will increase productivity and save energy and bandwidth.

(6) Congestion

Congestion causes packets to be delayed and lost, both of which are essential parameters in the performance of an IoT-based smart grid. Because some smart grid applications are sensitive to latency, it is crucial to minimize communication latency in these systems. For many IoT-based smart grid systems, more simultaneous messages should be sent from multiple devices without delay or loss of packets. This does not mean increasing bandwidth, but rather minimizing the messages sent by IoT devices to each HAN gateway, for which the number of nodes and gateways must be carefully selected.

(7) Ability to cooperate and integrate packages

Interoperability is defined as the ability of two or more heterogeneous networks/devices to exchange information and use the information exchanged in a standard function. IoT-based smart grid systems consist of a large number of different IoT devices and gateways that differ in specifications, functionality, and resources, as well as communication stacks and protocols. Lack of interoperability and coordination of devices is a severe obstacle to IoT-based smart grids. One of the proposed solutions to help achieve smart grids is to convert proprietary protocol networks to IP-based networks.

(8) Big Data control

In addition to creating higher costs associated with storing and processing large volumes of data, the integration of IoT technology with the smart grid imposes a more significant burden on IoT communication networks. Information in the smart grid includes energy consumption, customer load demand, recorded data of advanced meters, power line errors, etc. Using bandwidth and high data rates, as proposed by LTE, increases the ability to carry data but creates bottlenecks elsewhere. As a result, power utilities need to design systems with better capabilities for storing, managing, and processing collected data.

(9) Need for standardization

Standardization is essential for compatibility, interoperability, reliability, and security. Although research on IoT and IoT standardization has been ongoing, no specific IoT-based standardization activities have been conducted to date. Although the standardization of IoT data collection, under the name One M2M, is underway, it has not been well received, and the energy industry views it as an added burden and unsuitable for limited devices. The OMA standard for LWM2M[5] has become more popular due to its simplicity.

De facto standards have appeared organically on the web with the widespread use of what are commonly referred to as open-source or open-access software components. Although these standards may eventually be applied to IoT-based smart grid systems, security issues still require more immediate solutions which are not covered by these standards.

(10) Security issues

Extensive use of IoT technology in smart grids can lead to various security vulnerabilities. Since the monitoring and control of IoT-based smart grid systems is done in the open Internet, and this space has no more security than Internet-based security and lower security than managed mobile and fixed networks, Therefore, it is more vulnerable to cyber-attacks. An attacker can upset the real-time balance between energy production and energy consumption by altering data generated by smart objects or sent by power utilities, causing significant financial losses to the power utility and customers. At present, probabilistic analysis in the IoT-based smart grids has been proposed and considered to increase security. Security considerations that should be prioritized for IoT-based smart grids include:

- Limited resources
- Privacy
- Trust management
- Authentication and access permission
- Data integrity
- Cyber-attacks
- Scalability

[5] Lightweight M2M.

- Reliability
- Identification.

17.8 Conclusions

This chapter gives an overview of IoT and its associated business models. In general, IoT is a concept to describe a not-so-distant future in which physical objects connect to the World Wide Web and interact with other objects. In order to implement IoT, it is necessary to go through four stages of data collection, data transmission through the communication network, evaluation and estimation of data, and meeting the needs of users. Nowadays, IoT has entered various fields and has the ability of making all such systems smart. Therefore, topics with major priority, such as existing architectures, operating systems, data collection to above issues, storage, management and processing, networking, platform, technologies, and IoT security, were discussed in this chapter.

Due to the effects of IoT elements on each other and their interactions, and also due to the pervasiveness of this concept in other areas such as health, agriculture, etc., different ecosystems have been proposed in order to identify and study more actors and their relationships in IoT. After introducing the IoT technology, the smart grid, actually the most modern type of IoT-based smart grid, and related concepts are considered. Also, this chapter gives information on the architecture of the smart grid, its infrastructure and components, and in particular, the smart distribution network. The effects of IoT on the distribution network include the management of electric vehicles (EVs), aggregation of distributed energy resources (DERs), smart distribution substations, demand-side management (DSM), DR, and many other factors that increase the efficiency of the distribution network and the entire power system.

In the latter part of the chapter, the IoT business ecosystem and the conceptual model of the smart grid, besides their businesses, are investigated. In fact, by extracting the businesses of each of them and further combining them, the business model canvas related to the IoT-based smart distribution network was obtained. Finally, the problems and challenges of the IoT-based smart distribution network were pointed out and described.

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