Chapter 16
Clarifying the Concept of Smart Service System

Chiehyeon Lim and Paul P. Maglio

Abstract A new trend of smart service systems is emerging. Technology is applied intensively to alleviate the cognitive and behavioral load of customers and improve the operations of service systems, thereby enhancing value. Despite the significance of smart service systems in this connected and data-rich world, knowledge on this concept remains insufficient. This chapter builds a theoretical background for smart service systems research. Motivated by recent cases of smart service systems, this chapter reviews the definitions and characteristics of smart service systems discussed in existing studies; integrates empirical insights from studies on the design and development of smart service systems; and further explores the nature of smart service systems by analyzing texts from the scientific literature, news articles, and end-user opinions. By integrating all the information, this chapter aims to clarify the concept of smart service system. Using the proposed conceptual framework and related studies as basis, this chapter also categorizes smart service systems into three types according to the portion of customer roles in technology-based value co-creation: smart self-service, smart super service, and smart interactive service systems. Finally, based on the proposed conceptual framework, this chapter discusses future research topics related to the concept of smart service system, such as autonomous service system as a new type of service system that requires a minimum level of human–thing interaction but works mainly based on thing–thing interaction. This chapter would serve as basis for studying and developing smart service systems.

Keywords Smart service · Smart system · Smart service system · Definition · Categorization

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C. Lim (✉)
Ulsan National Institute of Science and Technology, Ulsan, Republic of Korea
e-mail: chlim@unist.ac.kr

P. P. Maglio
University of California, Merced, Merced, CA, USA
e-mail: pmaglio@ucmerced.edu

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16.1 Introduction

Service systems in transportation, retail, healthcare, entertainment, hospitality, and other areas are configurations of people, information, organizations, and technologies that operate together for mutual benefit (Maglio et al. 2009). Service systems have become "smarter" over time with the increasing use of technology in the systems (Lim et al. 2016). Smart service systems can be found in homes (Alam et al. 2012) as well as the energy (Strasser et al. 2015), healthcare (Raghupathi and Raghupathi 2014), and transportation sectors (Pelletier et al. 2011), among many others. As the concepts of service system and smartness intertwine, the academia, industry, and government pay significant attention to the concept of smart service system (e.g., Maglio et al. 2015; IBM Smarter Cities Challenge 2016; NSF 2016). This concept is meaningful in developing and using technology, such as the Internet of Things (IoT) and artificial intelligence (AI), because it represents the ultimate application and integration of technology for value creation for people (Ng and Vargo 2016).

Despite the widespread application and research on smart service systems, knowledge on this concept for its development remains inadequate (Maglio et al. 2015; Larson 2016). This chapter aims to contribute to building a theoretical background about the concept and stimulate debate about the sufficiency of existing efforts at academic and practical levels. Establishing common ground for central terms is essential for scientific progress (Boehm and Thomas 2013); thus, development and innovation in smart service systems require a shared vocabulary across multiple fields (Larson 2016). This chapter aims to establish a common ground necessary for integrating perspectives and capabilities to encourage the research and development of smart service systems and contribute to synergy among different research fields and application areas.

Section 16.2 reviews emerging cases of smart service systems in practice from a service science perspective to motivate the readers. Section 16.3 reviews the definitions and characteristics of smart service systems discussed in existing studies to help the readers develop a basic understanding of smart service systems. Section 16.4 reviews studies on the design and development of smart service systems to help the readers understand data-based value creation mechanisms of smart service systems. Section 16.5 introduces the authors' findings from analysis of 5378 scientific articles, 1234 news articles, and 444 user opinions related to smart service systems (e.g., keywords, research topics, and technology factors of smart service system) to help the readers understand the diverse features and core of smart service systems at the same time. Section 16.6 aims to clarify the concept of smart service systems by integrating findings from the previous sections. Section 16.7 integrates the proposed conceptual framework and related studies on service categorization and value co-creation to categorize smart service systems according to the portion of customer roles in technology-based value co-creation. Section 16.8 discusses promising future research topics related to the concept of smart service system, such as the service systems analytics and engineering and autonomous service system. Section 16.9 concludes this chapter.

16.2 Observation on Emerging Cases of Smart Service System

Value may be co-created between customers and firms (Prahalad and Ramaswamy 2002) or between any two actors (Vargo and Lusch 2016). More generally, value is constellated by a network of multiple actors and their interdependent relationships (Normann and Ramirez 1993). Value co-creation and value constellation are powerful concepts in analyzing and designing service systems (Payne et al. 2008; Patrício et al. 2011) because these concepts enhance the degrees of freedom to find fresh and innovative solutions for value creation, aside from existing product or service concepts (Lusch and Nambisan 2015).

This chapter takes a service science—a value co-creation conscious—perspective in viewing this connected and data-rich economy. From this perspective, the essence of the IoT (Atzori et al. 2010) is the enhanced connectivity between stakeholders that may increase encounters for value co-creation or constellation, whereas the term "big data" (George et al. 2015) pertains to the increased types and amounts of traces of the value co-creative activities and interactions within a service system that can be used in understanding and improving the activities and interactions.

Increased connectivity and the proliferation of data produced various forms of service in which stakeholders can monitor, be aware, and manage connected things and other stakeholders better than before. People call such services "smart" may be because of this intellectual property. For example, automobile manufacturers analyze car conditions and driving data collected from connected cars, and they provide various types of useful information to assist drivers on fuel efficiency, safety, consumable, and navigation (Lim et al. 2018a). Smart band-based fitness tracking services collect data from daily life, such as behavior, health, and food menu data, to help people achieve specific fitness-related goals, such as walking 10,000 steps a day (Takacs et al. 2014). Other examples include tire pressure monitoring (Velupillai and Guvenc 2007), vehicle fleet management (Volvo 2009), screen golf training (Jung et al. 2010), and precise farming solutions (Lim et al. 2012).

Apart from commercial examples, smart service systems are emerging in public domains (Lim et al. 2018e). The Seoul government collected data from city buses, identified patterns and demands of city bus usage at midnight, and subsequently improved the midnight bus services for citizens (NIA 2013). Waste management in Delhi collected data from trash bins using radio frequency identification tags and scheduled trash collection locations and time (Purohit and Bothale 2011). Air pollution monitoring in London analyzed data from pollution sources across the city along with European weather forecasts to create a pollution map of London. Precipitation monitoring in Rio de Janeiro used a flood prediction model based on land survey data, precipitation statistics, and radar data (Kitchin 2014). Transportation management in Singapore collected data from roads and taxis to anticipate future traffic and control traffic lights (Lee 2013).

A common aspect of these cases is the use of sensor data collected from connected things and people. With recent advancements in sensing technologies, various kinds and massive amounts of data are collected from individuals and objects through sensor-equipped consumer electronics and industrial engineering systems (Porter and Heppelmann 2014). Human-generated data involve a hypothesis or bias of recorders, whereas sensor data are natural records that reflect real behaviors of people and operations of objects. One difficulty in managing and improving a service system, which is sometimes conceptual, was a lack of data required to track, measure, model, modify, control, and manage individual behaviors and object operations within the service system in question. The recent advancements in sensing technologies unlock this limitation and provide numerous opportunities for engineering service systems. Thus, the degree of freedom to develop smarter service systems is increasing. From a service science perspective, using sensor data contributes to operationalizing or even automating value co-creation among connected people and things, and this is why smart service systems are meaningful to people (for their value creation). The introduced cases of smart service systems illustrate this advancement.

16.3 Definitions and Characteristics of Smart Service System

Smart service systems are described with keywords such as learning, adaptation, monitoring, decision making, sensing, actuation, coordination, communication, control (NSF 2016), viability, open, optimization, intelligence (De Santo et al. 2011), compliance, sustainability, data analytics, cognitive system, service (Spohrer and Demirkan 2015), self-reconfiguration, ICT, connection (Carrubbo et al. 2015), wise, interacting (Oltean et al. 2013), people, AI, real-time, interconnected, interactivity, context awareness, proactive, preventive, IT (Gavrilova and Kokoulina 2015), self-detection, self-diagnostic, self-corrective, or self-controlled (Maglio and Lim 2016). Sectors that incorporate smart service systems include city, government, (e.g., smart city) (Lim et al. 2018e), health (e.g., smart healthcare) (Mukherjee et al. 2014), energy (e.g., smart grid) (Strasser et al. 2015), transportation (e.g., smart car) (Pelletier et al. 2011), and even manufacturing (e.g., smart factory) (Lee et al. 2014).

Table 16.1 lists the definitions or descriptions of smart service system. These definitions and descriptions are consistent in that they specify capabilities or requirements of smart service system (e.g., the capability of self-adaptation and requirement of technology incorporation) but emphasize different capabilities or requirements. A common requirement emphasized by most studies is intensive data use. Using this observation as basis, we can understand smart service systems are data-based service

Table 16.1 Definitions or descriptions of smart service system

Source	Definition or description
NSF (2016)	A "smart" service system is a system that amplifies or augments human capabilities (Ng 2015) to identify, learn, adapt, monitor and make decisions. The system utilizes data received, transmitted, or processed in a timely manner, thus improving its response to future situations. These capabilities are the result of the incorporation of technologies for sensing, actuation, coordination, communication, control, etc.
Barile and Polese (2010)	Smart service systems may be intended as service systems designed for a wise and interacting management of their assets and goals, capable of self-reconfiguration (or at least of easy inducted re-configuration) in order to perform enduring behavior capable of satisfying all the involved participants in time. . . . Because smart service systems inevitably involve multiple actors, the organizational configurations need to take account of network theory—especially the networking forces and enablers required to keep the system tight and focused towards its goals
Medina-Borja (2015)	A smart service system is a service system capable of learning, dynamic adaptation, and decision making based upon data received, transmitted, and/or processed to improve its response to a future situation
De Santo et al. (2011)	Smart service systems are open, according to the logic of viable system approach, and capable of simultaneously optimizing the use of resources and improving the quality of the services provided. ... In this sense the intelligence of smart service systems derives not from intuition or chance, but from systemic methods of learning, service thinking, data collection, rational innovation, social responsibility and networked governance
Spohrer and Hamid (2015)	In the era of cognitive systems, smart service systems will increasingly include cognitive or digital assistants (e.g., Watson and SIRI-like systems) for all occupations and societal roles. It is foreseeable that smart Service Science research focus on leveraging advances in AI, big data-enabled intelligence and cognitive computing, and innovating to enable the creation of intelligent technologies and societies that are integrating well with human societies
Spohrer and Demirkan (2015)	Smart service systems are ones that continuously improve (e.g., productivity, quality, compliance, sustainability, etc.) and co-evolve with all sectors (e.g., government, healthcare, education, finance, retail and hospitality, communication, energy, utilities, transportation, etc.). ... Because of analytics and cognitive systems, smart service systems adapt to a constantly changing environment to benefit customers and providers. Using big data analytics, service providers try to compete for customers by (1) improving existing offerings to customers, (2) innovating new types of offerings, (3) evolving their portfolio of offerings and making better recommendations to customers, (4) changing their relationships to suppliers and others in the ecosystem in ways their customers perceive as more sustainable, fair, or responsible
Spohrer (2013)	Smart service systems are instrumented, interconnected, and intelligent. Instrumented means sensors, sensors everywhere—more of the information (real-time and historical, as well as monte carlo predictive runs) that stakeholders, providers, customers, governing authorities,

(continued)

Table 16.1 (continued)

Source	Definition or description
	etc.—need to make better win-win (value co-creation, capability co-elevating) decisions is available. Interconnected means people have easy access to information about a particular service system, as well as others that interact with it via value propositions, perhaps displayed on their smartphones. Intelligent means recommendations systems that work to provide stakeholders useful choices—for example, Watson-style recommendation systems, or Amazon-style recommendation systems
Carrubbo et al. (2015)	Smart service systems can be understood as service systems that are specifically designed for the prudent management of their assets and goals while being capable of self-reconfiguration to ensure that they continue to have the capacity to satisfy all the relevant participants over time. They are principally (but not only) based upon ICT as enabler of reconfiguration and intelligent behavior in time with the aim of creating a basis for systematic service innovation (IfM IBM 2008) in complex environments (Basole and Rouse 2008; Demirkana et al. 2008). Smart service systems are based upon interactions, ties and experiences among the actors. Of course, among these actors, customers play a key role, since they demand a personalized product/service, high-speed reactions, and high levels of service quality; despite customer relevance, indirectly affecting every participating actor, smart service systems have to deal to every other actor's behavior, who's expectations, needs and actions directly affect system's development and future configurations. The smarter approach applied to healthcare is called "smarter healthcare". As IBM highlights, a smarter healthcare system is obtained through better connections for faster, more detailed analysis of data
Oltean et al. (2013)	Smart service systems may be intended as service systems designed for a wise and interacting management of their assets and goals and capable of self-reconfiguration in order to perform enduring behavior capable of satisfying all the involved participants in time
Massink et al. (2010)	Common recurring elements of smart service systems are: spaces; displays; sensors; users. Users will interpret information on displays and carry out actions as a result of what has been read
Lim et al. (2016)	Smart service systems are those service systems in which connected things and automation enable intensive data and information interactions among people and organizations that improve their decision making and operations. Thus, transforming a service system into a smart service system means improving the decision making and operations within the service system with connected things and automation. As the definition indicates, a smart service system consists of four components: (1) connected things, (2) automation, (3) people and organizations, and (4) data and information interactions
Gavrilova and Kokoulina (2015)	The term "smart" implies two main properties. First, it highlights anthropomorphic features of the smart service. For example, technology research company Gartner, Inc. claims that smart technologies are ". . . technologies that do what we thought only people could do. Do what we thought machines couldn't do" (Austin 2009). Second, term "smart" is usually related to artificial intelligence (i.e. intelligence of

(continued)

Table 16.1 (continued)

Source	Definition or description
	machine) “[. . .] because it is impractical to deploy humans to gather and analyze the real-time field data required, smart services depend on “machine intelligence” (Allmendinger and Lombreglia 2005). ... Smart service systems often have the following characteristics of the intelligent system: Self-configuration (or at least easy-triggered reconfiguration) (Barile and Polese 2010), Proactive behavior (capability for prognosis or preventive actions, as opposed to the reactive behavior) (Allmendinger and Lombreglia 2005), Interconnectedness and continuous interactivity with internal and external system elements (Gershenfeld et al. 2004). ... Smart service attributes include dynamic properties (without modelling of the changing environment; past-based modelling; stochastic modelling), intelligence (knowledge-based; data-based; content-based), Knowledge awareness (context-oriented; explicit knowledge; business intelligence), IT platform (mobile; SaaS; hybrid cloud; corporate servers), and elements (IT; people; hybrid)
POSTECH IME (2016)	A smart service system refers to a system that delivers various services effectively and efficiently by considering the needs and context of stakeholders through smart technologies. Smart service systems providing smart service offerings such as adaptive control, prognostic monitoring, personalized guidance, and user-friendly interfaces are flourishing in business and society

systems, in which data use contributes significantly to value creation. “Smart” modifies behaviors and operations of people, operations and condition management of organizations and things, and interactions within the service system. Sensing from things and people within the service system produces data that indicate these behaviors, operations, conditions, and interactions. Data analytics contributes to the effectiveness and efficiency of these processes. Data analytics is core to smart service systems given the capability for continuous monitoring and learning with data. For instance, customer data may be converted into information that is useful in customer value creation processes in service systems and also can be used to adjust service operations (e.g., use of energy usage data for energy management). Imagining a smart service system without intensive use of data is difficult. Thus, a key to transform service systems into smart ones lies in exploiting data.

16.4 Design and Development of Smart Service System

The findings from the previous sections show that a smart service system features a data-based value creation mechanism. Previous studies on the design and development of smart service systems provide further insights into data-based value creation mechanisms of smart service systems. This section briefly introduces findings from the studies in Table 16.2.

Table 16.2 Studies on the design and development of smart service system

Study	Brief description	Related service system
Lim et al. (2018a)	Designed car infotainment services for individual drivers that use vehicle operations and condition data, based on analyses of 7.6 million trip data of 18,943 vehicles (vehicle operations data) and 3662 cases of warning code occurrences (vehicle condition data)	Smart transportation
Lim et al. (2018d)	Designed driving safety enhancement services for commercial drivers that use vehicle operations data, based on analyses of operations data of commercial vehicles (278 buses, 46 taxis, and 931 trucks) and accident data of commercial vehicle drivers (4289 bus, 1550 taxi, and 490 truck drivers)	
Kim et al. (2018)	Designed an eco-driving support service for bus drivers that use vehicle operations data, based on analyses of bus operations and fuel consumption data of 33 bus drivers	
Winkler et al. (2016)	Designed and implementing a thermal comfort enhancement service for building occupants that uses building energy operations data and occupant feedback data	Smart building
Kim et al. (2014a)	Designed hypertension patient management services that use a national health insurance database, based on analyses of a sample data from the database for one million people for 9 years (2002–2010)	Smart health
Kim et al. (2016)	Designed a smart wellness service for college students that use daily behavior data of students, with an IT company and a student counseling center at a university based on data from 47 students	
Kim et al. (2014b)	Designed health-related data-based services for health-related stakeholders with a government organization, based on interviews with 34 experts such as doctors, public health scientists, managers and executives in the industry, and government employees	
Chung and Park (2016)	Proposed a personal health record (PHR) open platform based smart health services using the distributed object group framework for managing chronic diseases	
Yu et al. (2011)	Designed a home portal service with a smart door interface which combines virtual and physical door control and provides the place for home members to communicate each other no matter he is at home or not	Smart home
Cai and Li (2014)	Designed a micro grid renewable energy service system for an island that uses wind, photovoltaic and biomass energy	Smart energy
Perera et al. (2014)	Proposed a "Sensing as a Service" model based on IoT infrastructure for smart cities, such as waste management and smart agriculture services	Smart city
Maglio and Lim (2016)	Categorized design models of smart service system into four groups according to the source and usage of data: smart operations management, smart customization and prevention, smart coaching, and smart adaptation and risk management services	Any smart service system

From these studies, we can derive a generic mechanism of data-based value creation in smart service systems. Each study focused on a specific part of the spectrum from data to value creation in smart service systems. Considering these studies, smart service systems, regardless of cases, entail the collection of data from certain sources, creation of useful information on the data sources through data analysis, and delivery of information to users to help them create value. More specifically, data-based value creation in smart service systems involves at least nine factors: (1) data source, (2) data collection, (3) data, (4) data analysis, (5) information on the data source, (6) information delivery, (7) information user, (8) value in information use, and (9) provider network (Lim et al. 2018b).

Data source (factor 1) includes specific objects such as vehicles, facilities such as city infrastructure, management activities such as city administration, and customers such as drivers and citizens. The methods of data collection (factor 2) include using sensors, recording logs of IT system users, and crowdsourcing of opinion data. Data (factor 3) include condition traces of engineering systems, event logs of business systems, health and behavioral records of people, and bio-signals of animals. The methods of data analysis (factor 4) include using specific algorithms pre-installed on servers and expert knowledge, which entail time for decision making.

Information (factor 5) created from data analysis indicates interested facts about the original data source. In many cases, the terms "data" and "information" are used interchangeably. For smart service systems, this chapter distinguishes data from information based on the data–information–knowledge–wisdom (DIKW) hierarchy (Braganza 2004): Data are raw materials and ingredients of information, and information is the outcome of the data analysis used for a specific purpose (Lim and Kim 2015). The methods of information delivery (factor 6) include e-mail, phone calls, smartphone applications, or onboard displays in vehicles (Lim and Kim 2014). Information user (factor 7) includes drivers who use car infotainment services, parents who utilize baby-monitoring services, and citizens and local organizations that use services in smart cities. A common aspect of these studies in Table 16.2 is that each study focused on specific stakeholders (i.e., information users) of a service system as main targets for data-based value creation, such as passenger car drivers (Lim et al. 2018a), riders and drivers of commercial vehicles (Kim et al. 2018), building occupants (Winkler et al. 2016), and people and government (Kim et al. 2014a, b).

Examples of value (factor 8) include evidence-based health management, improvement of operational processes of certain service systems, and prevention of potential user problems. Note that value is not created until users actually use the received information for a specific purpose. In other words, value is created in information use (Vargo and Lusch 2004; Lusch and Nambisan 2015). For example, the safety of driving can be improved when information for safe driving is used by drivers and health can be improved when health-related advice information is used. The provider network (factor 9) consists of the main service provider (which interacts with customers) and its outsourcing partners, such as sensor manufacturing, data management, and analytics companies. Data and information can be digitized into bits unlike other types of deliverables in business; thus, outsourcing is common in smart service systems.

A service concept is a description of what needs to be done for customers and how this can be done (Edvardsson and Olsson 1996; Goldstein et al. 2002; Kim et al. 2012). Thus, designing services requires understanding the things that constitute the what and how of service (Lim et al. 2012; Kim et al. 2013). Service design is difficult because a design space is wide and complex, which is attributed to the variety of the what and the how of the candidates (Lim et al. 2018c). The nine factors embrace key areas of smart service system analysis and design: (5) what to deliver, (8) why, (7) to whom, (1–4) how to produce it, (6) how to deliver it when and where, and (9) who creates and delivers it. The use and management of data in smart service systems should consider these areas to facilitate value creation with.

16.5 Understanding Smart Service System Through Text Mining

Including the intensive use of data discussed in the previous sections, smart service systems involve diverse features. The functions and operations of smart service systems depend on sensing (Sim et al. 2011), big data (Maglio and Lim 2016), computation (Lee et al. 2012), and automation (Jacobsen and Mikkelsen 2014). Customer (Wuenderlich et al. 2015) and business aspects (San Roman et al. 2011) must be considered as well. A search for “smart service system” in the Web of Science generates more than 5000 results across engineering, computer science, information systems, control, transportation, healthcare, and other fields. Given the wide range of various research related to smart service systems, a unified understanding of the concept across different fields may facilitate development and innovation; such unification would promote the use, integration, and improvement of technologies from a broad and application-oriented perspective. However, such integrative work is difficult to achieve because of the variety and number of studies and applications related to smart service systems. Text mining is an appropriate method to address this challenge given its ability to automatically explore aspects and areas of smart service systems in a comprehensive manner (Lim et al. 2017).

Lim and Maglio (2018) developed a unified view of smart service systems by mining text related to these sorts of systems. The text they analyzed includes scientific literature, news articles, and user opinions. Their analytics method uniquely incorporates metrics to statistically measure the importance of word-features of data and unsupervised machine learning algorithms, such as spectral clustering (Von Luxburg 2007) and topic modeling (Blei et al. 2003), to capture the essence of the data. Their analysis of 5378 scientific studies, 1234 news articles, and 444 opinion surveys identifies statistically significant keywords, research topics, technology factors (sensing, connected network, context-aware computing, and wireless communications), a definition, application areas, and end-user-perceived values. This section briefly reviews their findings to advance the readers' understanding about smart service systems after the previous sections.

Findings from the analysis of 5378 literature data indicate that a smart service system requires technologies for networking, data and information processing, control, communications, devices, and applications to provide specific functions to system users. Related topics in the literature include "design of smart service systems," "sensing," "Internet/Web of Things," "wireless networks/communications," "mobile devices," "cloud computing/environment," "security," "smart home," "smart health," "smart energy management," and "smart city." Lim and Maglio (2018) also identified a set of 53 generic word-features that may represent the generic structure of smart service systems, including "thing," "internet," "context-aware," "control," "sensing," "wireless," "location," "access," "communication," "computing," and "data." An exploratory factor analysis of the 53 generic word-features of 5378 articles from the literature (i.e., those extracted from the 5378 by 53 matrix dataset that may represent the generic structure of smart service systems) revealed four key technology factors of (any) smart service systems; based on factor loading of the 53 word-features (i.e., variables), these four factors can be called "connected network," "sensing," "context-aware computing," and "wireless communications."

Using the four factors and the list of 53 generic words as basis, Lim and Maglio (2018) propose a statistically significant definition of smart service system: "A smart service system is a service system that controls things based on the resources for connected network, sensing, context-aware computing, and wireless communications". Examples of the resources include specific environments, infrastructure, devices, and applications (software). Examples of the things to be controlled include specific objects, processes, and users. These definitions and examples are meaningful in that they consist of the important words quantitatively identified from the literature data.

Findings from the analysis of 1234 news data indicate that application areas of smart service systems can be categorized into "smart device," "smart environment," "smart home," "smart energy," "smart building," "smart transportation," "smart logistics," "smart farming and gardening," "smart security," "smart health," "smart hospitality," "smart education," and "smart city and government." These 13 areas can be distinguished according to the type of application: Smart device and environment are resource-type areas, which are required in any kind of smart service system. Smart home, energy, building transportation, logistics, farming and gardening, security, health care and management, hospitality, and education are business system-type areas. Smart city and government systems are a public administration-type area. Common keywords found from the news data include "device," "product," "app," "data," and "information." This list implies that the essence of smart service systems, which have been discussed in various news articles, is the use of a device or product with a smartphone application to collect data from people and to deliver information to them. A network analysis of these areas indicate that a smart service system is related to other systems across different contexts of the users (e.g., smart health and smart home are highly relevant, while smart transportation is one of the key businesses in smart cities) and resources (e.g., smart device and environment). Thus, achieving synergy between different smart service systems will effectively streamline the development and operations of a system.

Findings from the analysis of 444 user opinion data indicate that people used the following phrases to describe values of the smart service system they like: “ask Siri thing,” “easy order,” “people make money,” “behavior make decision,” “computer make choice,” “people living assisted,” “advance contextual awareness,” “better sleep tracking,” “monitor many different,” “ready go get,” “people want know,” “house living remotely,” “allowing happen without,” “accomplished less time,” “ability reduce load,” “make job,” “manage human resource,” and “surroundings make decision.” Based on this result and a detailed reading of the full list of 444 opinion data, we found that the end-user-perceived values of smart service systems may include (1) save time, cost, or other resource; (2) reduce undesired outcomes; (3) increase desired outcomes; (4) allow things to happen without something; (5) monitoring or tracking ability; (6) know the user or the contexts; (7) easy or autonomous decision making; and (8) easy order or remote control.

Combining all the findings, Lim and Maglio (2018) describe smart service systems, such as smart homes and health, energy, transportation, and hospitality systems, as follows: Smart service systems automate or facilitate the value-creating activities of users and providers based on technological resources for connected network, sensing, context-aware computing, and wireless communications. These systems enable users to get their jobs done efficiently and effectively. Sensing of data obtained from connected networks of people and things is the key mechanism of smart service systems. Context-aware data analysis creates information that can be used by users to manage and improve their things (e.g., specific objects, processes, and resources) and people concerned. User-friendly smart devices enhance the delivery of benefits of smart service systems to users through wireless communications. The design of a smart service system can be improved by considering the factors and values of the system in question and seeking a synergy with other application areas.

16.6 Clarification of the Concept of Smart Service System

Each of the previous sections emphasized specific characteristics of smart service systems. Section 16.2 emphasized the importance of sensor data collected from connected things and people. Section 16.3 emphasized that capabilities of smart service systems require a data-based mechanism. Section 16.4 emphasized the importance of managing the spectrum from data to value creation in smart service systems. Section 16.5 emphasized the four technology factors required to create value, namely, connected network, sensing, context-aware computing, and wireless communications.

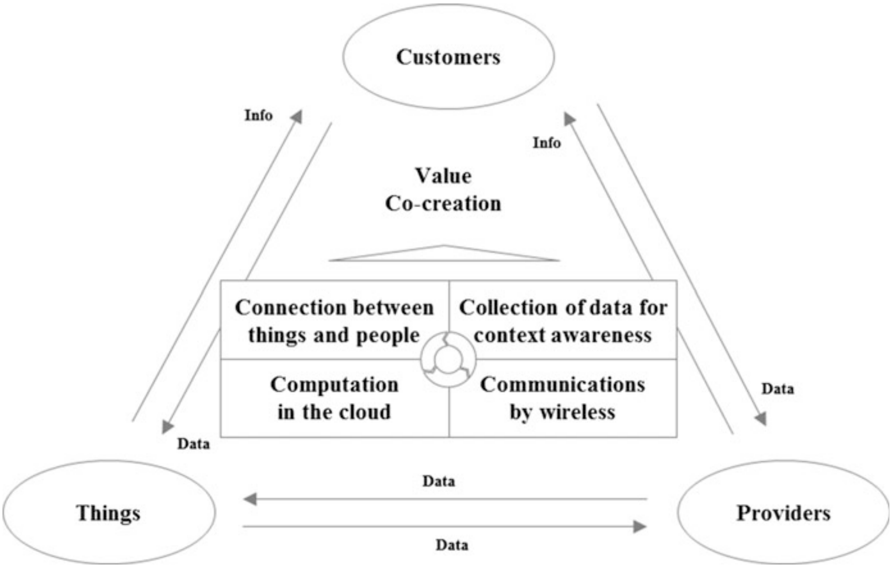

Fig. 16.1 Conceptual framework of smart service system

By integrating findings from the previous sections, this section aims to clarify the concept of smart service system. Smart service systems are service systems in which value co-creation between customers, providers, and other stakeholders are automated or facilitated based on a connected network, data collection (sensing), context-aware computation, and wireless communications. These systems enable customers to accomplish their tasks efficiently and effectively. Using data from people and things (e.g., specific objects, processes, and resources) is the key in smart service systems to manage and improve the value co-creation and system operations. Given this definition, a smart service system exhibits five essential attributes, namely, the 5Cs: (1) Connection between things and people, (2) Collection of data for context awareness, (3) Computation in the cloud, (4) Communications by wireless, and (5) Co-creation of value.

Figure 16.1 illustrates a conceptual framework of a smart service system based on the 5Cs. Customers and providers who are connected to each other co-create value through data and information communications. Data are collected from connected things (e.g., specific objects, processes, and resources), customers, and providers and then transformed into information through computational processes. Information generated from computational processes is used by the customers to use, manage, and improve their concerned things and people.

Connection between things and people is the first attribute that a smart service system should manage. Connected things include tangible goods directly used by customers, as well as dedicated infrastructures generally required by customers and providers; these goods and infrastructures can be connected to other things. We live in a connected world; the buzzwords "IoT," "Connected Car," or "Connected

Home" reflects our ability and desire to effectively control things around us. The development of a connected network of people and things, which is the base infrastructure for a system, is the groundwork for collection and communications in a smart service system. In fact, a connected network represents the network of "data sources" for smart service systems. Where to collect data is directly relevant to data use (i.e., purpose of service system) and to the scope and potential of a service system. IoT is crucial because IoT is about creating a cyber-physical infrastructure for connection. Technologies for data analytics, cloud computing, and mobile communications, among others, can effectively work together only with a connection infrastructure.

Collection of data from connected people and things is the second attribute of a smart service system. Data include condition traces of engineering systems, event logs of business processes, health and behavioral records of people, and bio-signals of animals. Given our capability for continuous monitoring and learning from data, data are the core resources for context awareness. The term "smart" pertains to information actions rather than to physical or interpersonal actions; hence, this term is inevitably related to the use of data. A major distinction between traditional and recent data collection is the data source (i.e., engineering systems versus human systems). Current sensing methods include physical plus social sensing. Physical sensing refers to a process conducted using physical sensors, whereas social sensing includes any type of sensing enabled or conducted by people without using physical sensors. Examples of social sensing include data collection from social network services, surveys, interviews, queries, and documents. Physical and social sensing from things and people within a service system produce data that indicate behaviors and operations of people, operations and condition management of organizations and things, and interactions within a service system. Data use contributes in the effectiveness and efficiency of these processes.

Computation is the third key attribute of a smart service system. Computational processes involve the use of specific algorithms and expert knowledge for decision making. Computation is the prerequisite for data and information communications in a connected network because these processes transform raw data into standardized data or information that enable machine-understandable data or human-understandable information. The key functions of smart service systems (e.g., context awareness, predictive and proactive operations, adaptation, real-time and interactive decision making, self-diagnosis, and self-control) can be created only through computation of specific data. This often requires several pre-tasks for data analytics, such as analysis planning, data cleaning, anonymization, aggregation, integration, and storage. Two of the key requirements of computation in smart service systems are cloud computing availability and security because of the distributed nature of connections in the service system.

Communications by wireless between people and things is the fourth attribute of a smart service system. The contexts of communications include machine-to-machine actuation and machine-to-human guidance. Thus, the issues of this attribute encompass the issues in communicating machine-understandable data and human-understandable information, such as visualization methods and other information delivery methods through auditory, olfactory, palate, and tactile stimulation in physical, virtual, and augmented reality. Although the same goods, infrastructures, and stakeholders can be involved in multiple service systems, interactions are relatively unique in each service system. Although technologies for connection, collection, and computing are fulfilled in a specific service system, the key to transforming such system into a smarter service system or to creating a new smart service system lies in improving the unique interactions within the system in question. As such, communications technology that facilitates interactions is crucial in any smart service system and is considered the circulating blood of the system.

Co-creation of value between customers and the provider of a service system is the fifth attribute of a smart service system. Value creation is the core purpose and central process in economic exchange. Any type of socio-technical service system involves value co-creation that brings different stakeholders together to jointly produce a mutually valued outcome. In this respect, the development and use of technologies ultimately aim for enhanced or new value creation. Examples of value co-creation stakeholders include customers of IT goods, manufacturers, government agencies of infrastructure, and application developers. The first four attributes represent the technological resources for smart service systems, whereas the fifth attribute represents the application objective of various resources. In fact, the first four attributes of smart service systems contribute to increasing the opportunities for active value co-creation. As we become more connected, encounters for value co-creation increase; as we collect and compute more quality data (quality in terms of variety and volume), the informational or intellectual resources for value co-creation increase; and as we communicate more efficiently and effectively, the frequency and intensity of value co-creation increase.

Figure 16.1 indicates that smart service systems have a closed-loop mechanism. Data and information interactions within a service system are iterative, and stakeholders can develop their relationships and improve value co-creation continuously through a cycle of monitoring and learning. This feature shows the true importance of service system thinking for the use of various technologies. The direction of the evolution of smart service systems is clear, that is, continuous development of the loop of value co-creation by integrating technologies for connection, collection, computation, and communications. The real advantage of service system thinking is that it deviates from the existing technology concepts and focuses on the final function (i.e., application) that must be fulfilled.

The 5Cs are useful in describing and analyzing a smart service system. For example, a smart home can be defined as a service system that automates or facilitates value co-creation activities (e.g., lighting, cooking, temperature control, garage opening, and exercising) between residents and related stakeholders through in-home or home-around connectivity, collection of living-related data, computation for context awareness, and wireless communications achieved within or through a technology-equipped house. Similarly, a smart health service system automates or facilitates value co-creation activities among patients, healthy people, healthcare providers, and other stakeholders through connectivity among people, devices, and healthcare environment; collection of health-related data; computation for diagnosis and prognosis; and communications within or through technology-equipped people, living, and care environment.

Another significance of describing smart service systems in this manner is that the 5Cs provide a basis for interconnecting different fields, with emphasis on applications. Recent concepts, such as IoT, big data management, AI, cloud computing, and wearable devices, are related to smart service systems, wherein each concept corresponds to one or more system attributes. For example, wearable devices (e.g., smartphones, wristbands, and watches) are related to collection and communications and serve mainly as data collection and information delivery channels. AI is related to computation, whereas IoT is about connection. Moreover, each of the research fields related to smart service systems, for instance, electronic engineering on collection and communications, computer science on computing, and marketing and business on co-creation, may focus on one or some of the system attributes and seek synergy with different fields related to other attributes. A challenge for R&D projects is the integration of the expertise of different professionals into knowledge for value creation. The proposed concept of smart service system with its five attributes can guide the entire project team to work effectively in managing and improving a technology-based service system.

16.7 Categorization of Smart Service System

The conceptual framework of smart service system illustrated in Fig. 16.1 shows how technologies contribute to the interactions and value co-creation within a network of customers, providers, and things. By integrating the framework and related studies on service categorization (Frei 2006; Bolton and Saxena-Iyer 2009; Campbell et al. 2011; Wünderlich et al. 2013) and value co-creation (Payne et al. 2008), we can categorize different smart service systems into three types, namely, smart self-service, smart super service, and smart interactive service systems (see Fig. 16.2).

Payne et al. (2008) developed a process-based conceptual framework for understanding and managing a detailed mechanism of value co-creation. Their framework shows that customer value is co-created based on continuous interactions between customer and provider processes through encounter processes. From this perspective, services can be differentiated according to the portion of customer roles in value co-creation processes. In traditional self-services or classic reduction of customer variability (Frei 2006), such as the use of ATM and self-check-in hotels, the customer performs many of the tasks previously done by the provider. By contrast, the boundary can shift in the opposite direction. In traditional super services (Campbell et al. 2011) or classic accommodation of customer variability (Frei 2006), the provider performs many tasks previously done by the customer, such as a car rental service that delivers cars to customers or luxury hotel service. Meanwhile, in traditional interactive services (Bolton and Saxena-Iyer 2009), such as fitness

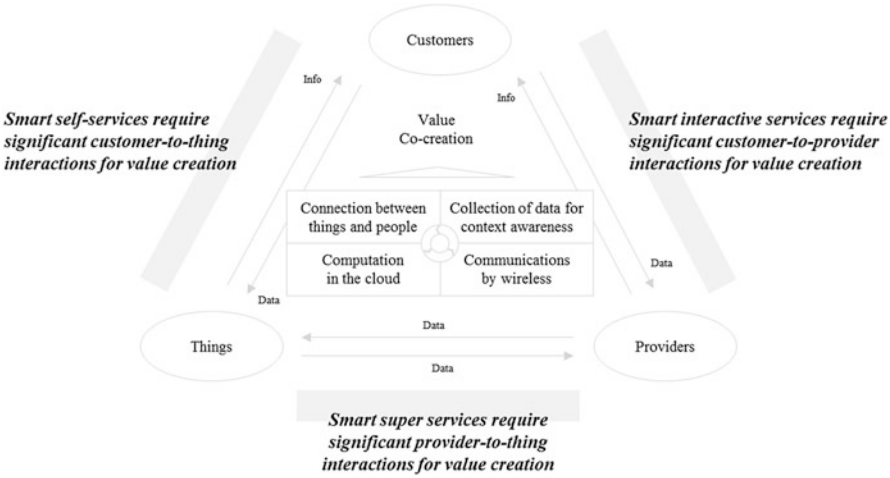

Fig. 16.2 Three types of smart service system

training and counselling services, interpersonal interactions between customer and employee are essential for value co-creation.

The four technology factors of smart service system (i.e., connection, collection, computation, and communications) have advanced all three types of service. For example, smart band-based fitness tracking services (Takacs et al. 2014) take the traditional role of fitness trainers and enable a smart self-service system for health management powered by the four technology factors (e.g., coaching capability for people). Such smart self-service systems require significant customer–thing interactions for value creation. By contrast, many equipment manufacturers take the traditional role of customers in maintaining and using equipment and enable a smart super service system powered by the four technology factors (e.g., optimization capability for equipment). Such smart super service systems significant provider–thing interactions for value creation. Meanwhile, a smart interactive service system "comprises not only an embedded technology within the product that communicates object-to-object but also personal interactions between the user and the service provider employee as part of the smart service delivery process" (Wünderlich et al. 2013). Examples include industrial remote interactive repair and online transportation network (e.g., Uber) services. Smart interactive service systems are somewhere in between the other two types and require significant customer-to-provider interactions for value creation.

Service systems depend not only on people, information, organizations, and technologies but also on their interactions, which have emergent consequences (Maglio and Lim 2016). Thus, managing the interactions among customers, providers, and things involved in the service system is key to improve value co-creation. Figure 16.2 shows how different types of smart service system improve the interactions with technology. Lusch and Nambisan (2015) provide a broadened view of service innovation based on the service-dominant (S-D) logic (Vargo and Lusch

2004) and describe the integration of the resources of a service system as the fundamental method to innovate the system. In the proposed conceptual framework of smart service system, the connection and communications factors mainly contribute to a tighter integration of resources (e.g., people and their concerned things), while the collection and computation factors are critical in creating new useful resources (e.g., data on the things, information for people, and enhanced knowledge of people). From this perspective, Fig. 16.2 further illustrates the three areas of technology-based service innovation: The integrative use of the four technology factors (i.e., connection, collection, computation, and communications) contribute to the smart self-service innovation by enhancing the controllability of customers over their concerned things; to the smart super service innovation by allowing providers to infiltrate into the value creation process of customers, embed themselves in the process, and take the roles previously done by the customer; and to the smart interactive service innovation by expanding and intensifying the interactions between customers and providers.

16.8 Future Research Topics

By integrating existing studies on smart service system in this chapter, a number of research issues have been observed. This section discusses the four following priorities: (1) service systems analytics and engineering, (2) operationalizing value co-creation in smart service systems, (3) autonomous service systems, and (4) extending the smart service system concept.

First, this chapter calls for research on service systems analytics and engineering. A system is "a combination of interacting elements organized to achieve one or more stated purposes" (ISO/IEC 2008). Human-designed systems, such as vehicles and transportation systems, have well-defined architectures and understood mechanisms of operation. For other systems, parts may be designed but the systems themselves may evolve, such as cities or universities, with system architectures and mechanisms emerging over time. Service systems tend to fall between fully designed and fully emergent systems, and their architectures or mechanisms are not yet clearly understood, although such an understanding is the key to engineering and improvement. One difficulty in engineering and managing complex service systems is the lack of data required to monitor and improve the system elements. However, with recent advances in sensing technologies, various kinds and massive amounts of data can be collected from the elements of the service system, such as people and physical goods.

This advancement contributes to unlocking the limitations of engineering and managing service systems, that is, a way of transforming specific service systems into smarter service systems. At least, the proliferation of (big) data alleviates two challenges in service systems engineering and management. First, articulating the concept, architecture, and mechanism of a service system was difficult because service systems are complex (Maglio et al. 2009) and fuzzy (Glushko 2013), in contrast to physical systems, such as vehicles and factories. Section 16.5 illustrates how newly available text data from social sensing can be used to understand the mechanism and define the concept of a specific type of service system, that is, the smart service system. Second, designing a service system was difficult because service systems involve numerous variabilities originating from customers (Frei 2006), contexts (Glushko 2010), and operations (Roels 2014). Section 16.4 illustrates how newly available physically sensed data from customer processes or operations within the service system in question can be used to design new services or improve existing services. Transforming specific service systems into smarter service systems requires understanding of the service system in question and modification of the system operations. Under the proposed framework of smart service system, it is apparent that data analytics can contribute to such understanding and modification. Research on using data through descriptive, predictive, and prescriptive analytics will contribute to understanding and improving service systems in multiple application areas.

Second, this chapter calls for research on operationalizing value co-creation in smart service systems. Many notable studies have discussed concepts, utilities, and mechanisms of value co-creation theoretically and empirically in marketing, information systems, innovation, design, and multidisciplinary contexts (e.g., Vargo and Lusch 2004; Maglio and Spohrer 2008; Payne et al. 2008; Vargo and Lusch 2016). Despite the emergence of a broad range of research on value co-creation over the last decade, a review of the literature revealed a surprising lack of work directed at providing frameworks to help organizations operate value co-creation with customers effectively and systematically, except for few related studies (Payne et al. 2008; Ulaga and Reinartz 2011; Smith et al. 2014). The fifth axiom of S-D logic states that "value co-creation is coordinated through actor-generated institutions and institutional arrangements" (Vargo and Lusch 2016). Thus, S-D logic indicates the research necessity of operationalizing value co-creation in service settings to account for all agents, organizations, and resources involved.

One difficulty in operationalizing value co-creation is the lack of data required to track, measure, model, modify, control, and manage individual customer behavior and perceptions (Lim et al. 2018f). Considering the field of industrial operations management before the emergence of "big data," data from production and business operations were routinely used to better operate specific processes (e.g., Linderman et al. 2003; van der Aalst and Weijters 2004). With recent advances in sensing technologies, various kinds and massive amounts of data are collected from individuals through sensor-equipped consumer electronics (Porter and Heppelmann 2014). Traditional survey or observation data on customers are essentially research data involving a hypothesis before data collection, whereas sensor data on customers are natural records being collected and archived independent of a specific research project, which reflect the real behavior and contexts of customers. From a marketing perspective, the IoT enables the Internet of Customers that creates many new types of customer touchpoints and provides opportunities for managing the customer relationship (Johnson 2016). In this context, it is the time to operationalize value co-creation with newly available data on customers.

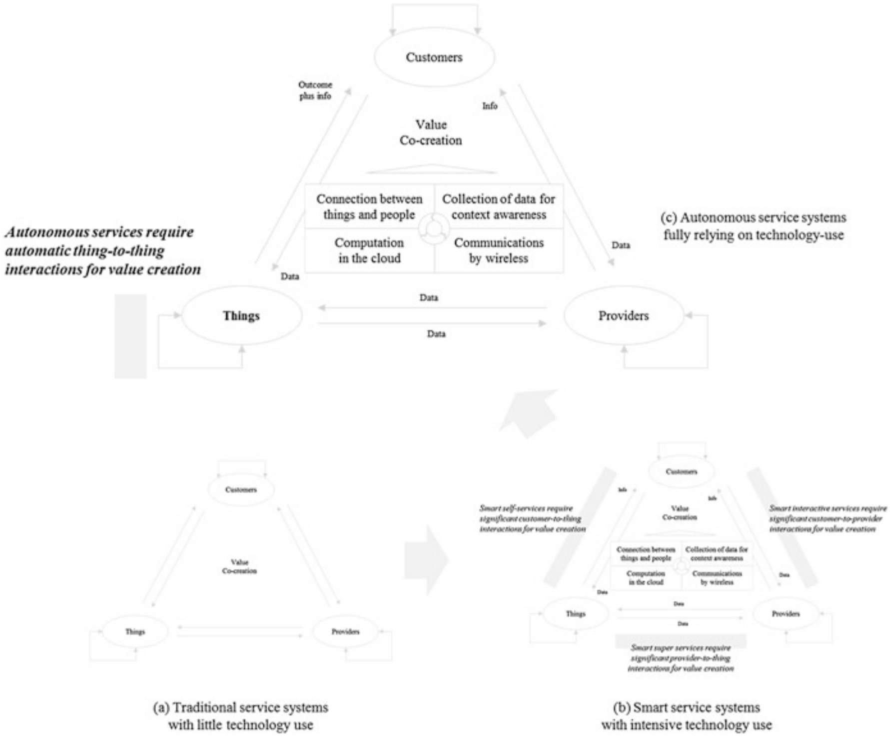

Fig. 16.3 Evolvement of service systems and emergence of the autonomous service system

As discussed, various kinds and massive amounts of data are collected in smart service systems from sensors located around people. Such newly available data can be used for operationalizing value co-creation on the connected network. The previous section illustrates that, for effective value co-creation, smart self-services operationalize customer–thing interactions using data from customers and things, smart super services operationalize provider–thing interactions using data from providers and things, and smart interactive services operationalize customer–provider interactions using data from customers and providers. However, only few studies addressed this topic though it is key to the application of the value co-creation concept and S-D logic in practice. Although the studies reviewed in Sect. 16.4 provide some insights into smart service system operations, most of the studies do not focus on the context of value co-creation. Research on operationalizing value co-creation in smart service systems will contribute to managing and improving service systems in this connected and data-rich world from a service science perspective.

Third, this chapter calls for research on autonomous service systems. The proposed framework of smart service system can be used to describe any service system as the network of customers, their concerned things, and providers is generic. From this perspective, Fig. 16.3 illustrates the evolvement of service systems according to the intensity of technology use in the service system network. Value is co-created through "the application of competences (knowledge and skills) by one entity for the benefit of another" (Vargo and Lusch 2004). In traditional service systems (Fig. 16.3a), customers employ the competences of providers to achieve specific goals and interact with concerned things. In the three types of smart service system (Fig. 16.3b), the interactions among customers, their concerned things, and providers are facilitated or automated based on the four technology factors (i.e., connection, collection, computation, and communications). In this continuum, a new type of service system that is rapidly emerging is the autonomous service system (Fig. 16.3c), such as service systems based on a self-driving car (e.g., Google) and a fully automated building (e.g., Edge in Amsterdam).

As shown in Fig. 16.3, interactions exist within customers, things, and providers. As recent AI can recognize and deliberate various things, we must pay specific attention to thing–thing interactions. In autonomous service systems, thing–thing interactions are fully automated and the things behave autonomously. Following Frei (2006), traditional "automation" technologies and modern "autonomous" technologies in service systems can be distinguished in terms of variability, with traditional "automation" technologies "reducing" and controlling variability (e.g., trains use specified routes and ATMs cover limited options) and modern "autonomous" technologies "accommodating" variability (e.g., self-driving cars use any route and AI-based financial services invest by themselves). Autonomy must incorporate automation technologies for the four technology factors of smart service system to be connected with, use data on, deliberate about, and communicate with humans and things. We are at a tipping point of the true integration of these factors for autonomy for monitoring, communication, context awareness, learning, predictive and proactive behavior, adaptation, optimization, real-time and interactive decision making, control, self-detection, self-diagnosis, self-reconfiguration, and self-control. As shown in Table 16.1 in Sect. 16.3, these terms have been used to describe smart service systems. Thus, the emergence of autonomous service systems means the emergence of truly smart service systems as indicated in the continuum shown in Fig. 16.3.

Autonomous service systems may be viewed as an ideal form of smart self-service systems in that customers only need to consider the outcome of the service system or the same of smart super service systems in that providers encapsulate their capability in the service system. However, autonomous service systems are clearly different for the adjacent types shown in Fig. 16.3 in that no or a minimum level of human–thing interactions is required and things take deliberate action on their own. Given a full automation of the interactions within things and consequent autonomous behavior and operations of the things, customers and providers (nearly) do not have to interact with each other and with the things.

In autonomous service systems, value co-creation processes are nearly automated by the things as humans only need to take (either consciously or unconsciously) the value in use produced and delivered by the things automatically. Many areas of smart service system, such as autonomous farming, building, energy, logistics, transportation, and security, can be evolved into autonomous service systems, whereas smart home, health, hospitality smart education, smart city, and government service systems require human interventions. In any case, what should be automated or whether and when automation will improve the overall value co-creation (or it should only be value creation) is unclear. Research on autonomous service systems from a service science perspective can extend the literature on value co-creation to the world of interactions within things and improve the partnership between humans and computers for value co-creation.

Finally, the smart service system concept proposed in this chapter should be further extended and studied in depth. This chapter has mainly focused on a digital data-centric perspective, such as that on the connection of different data collection sources to develop a smart service system with high-quality computation and communications functions for value co-creation. However, this perspective may be incomplete due to the limited scope of the reviewed studies on smart service systems and the authors' limited background in industrial engineering, computer science, and management. For example, this chapter has not fully covered the engineering perspectives on physical human–machine interaction (HMI) as well as those on physical control and actuation mechanisms. Within most of the existing smart service systems, humans interact with machines. Using advances in haptics and actuators enhances the interactions between them and improves function execution accuracy. For example, the ability to physically retrieve cash from an ATM or deposit a check may co-create more value than the action of checking the balance only. Thus, advancements in the HMI and control aspects of ATMs are important. The future AI-based smart banking service systems are not different and are required to be equipped with high-quality functions for HMI and controls. This requirement applies to other types of smart service system as well, such as physical driving with received information in smart transportation systems and physical intervention in smart health systems, which are adaptive to the patients' behavioral and bio-signal data. These perspectives are also important in autonomous service systems because humans are always involved and receive physical outcomes in such systems.

Our intention was not to propose an exhaustive concept of smart service system in one chapter but to clarify some important perspectives and elements of the concept. Value co-creation in smart service systems can be enhanced by advances in data collection and use, but also through the spectrum of engineering advances in actuation, such as a robotic hand exoskeleton that can provide an assistant service to a customer by reacting to the input provided through the electromagnetic waves from the customer (e.g., electromyography; Yun et al. 2017a, b). In general, the physical interaction of a machine with a human to co-create value is only possible because of the existence of both elements.

Although we believe the aforementioned perspectives are important, we could not state these perspectives in an earlier section because we could not find these from our data analytics and specific references focused on the smart service system concept. For example, in the factor analysis discussed in Sect. 16.5, we could not derive a control-related factor when we set up the number of factors as five or six, though "control" was one of the 53 generic word-features that may represent the generic structure of smart service systems. We believe future studies on the HMI and control aspects of smart service systems can extend our findings significantly. For example, factors about the physical actuators and physical interaction with technology can be added to the current nine factors of value creation mechanisms of smart service systems. The 5Cs can also be further extended to the 6Cs, including the following: (1) Connection between things and people, (2) Collection of data for context awareness, (3) Computation in the cloud, (4) Communications by wireless, (5) Control and actuation of physical elements, and (6) Co-creation of value. Smart service systems with a strong physical component, such as smart homes, transportation, and farming, may be described and developed with the extended 6Cs concept.

Likewise, other perspectives on smart service systems can be further investigated and added to the findings of this chapter. The level of service system smartness should also acknowledge the partnerships between machines and humans that interact to co-create value. For example, a team consisting of robotic assistant nurses, human nurses, human doctors, and surgery robots can co-create value with patients as they deliver smart health services to such patients. Strategies for the symbiosis, where the machine and the human interact in a perfect and harmonic way, should be studied and included in an extended smart service system concept. Indeed, no machine can complete the value co-creation process without the human, and no human can do it without the machine. Finally, the augmentation of human capabilities, such as vision, sensing, touching, hearing, and movement in smart service systems, can be investigated and integrated with all the aforementioned points.

16.9 Conclusion

This chapter takes a service science perspective in viewing service systems in this connected and data-rich economy, following the call for proposals on smart service systems by the NSF (2016). The concept of smart service system discussed in this chapter recognizes the smartness in modern service systems as multi-dimensional (i.e., the 5Cs). The concept can facilitate the application of a service science perspective to develop and use technologies for people for their value co-creation. Our work is significant in that the findings were derived from a literature review (Sect. 16.3), real projects with industry and government on the design and development of smart service systems (Sect. 16.4), and an analytics of 5378 scientific studies and 1234 news articles (Sect. 16.5). The findings in Sects. 16.6 and 16.7 aggregate the key concepts and areas of broad studies and applications of smart service system. Our work will bring significant clarification and elaboration to the definition of smartness in modern service systems. Smart people co-create value by creating connections between relevant things and the concerns of people, by collecting and computing data, and by communicating with things and people to address the concerns. This mechanism can be applied to describe and develop any type of smart service system. Following Larson (2016), the authors believe that this chapter would provide an effective framework for the design and development of smarter service systems across multiple disciplines.

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Chiehyeon Lim is an assistant professor in the School of Management Engineering at UNIST (Ulsan National Institute of Science and Technology). He obtained his B.S. (2009) and Ph.D. (2014) from the Department of Industrial and Management Engineering at POSTECH (Pohang University of Science and Technology). As part of his postdoctoral experience, he served as an assistant project scientist and lecturer in the School of Engineering at University of California, Merced. His research interests include smart service systems and service systems engineering and management.

Paul P. Maglio is a professor of technology management in the School of Engineering at the University of California, Merced. He holds an SB in computer science and engineering from MIT and a Ph.D. in cognitive science from UCSD. One of the founders of the field of service science, Dr. Maglio is currently Editor-in-Chief of INFORMS *Service Science,* and was lead editor of the *Handbook of Service Science* (Springer).