Service Systems, Smart Service Systems and Cyber-Physical Systems—What's the difference? Towards a Unified Terminology

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Abstract. As businesses and their networks transform towards co-creation, several concepts describing the resulting systems emerge. During the past years, we can observe a rise of the concepts Service Systems, Smart Service Systems and Cyber-Physical Systems. However, distinct definitions are either very broad or contradict each other. As a result, several characteristics appear around these terms, which also miss distinct allocations and relationships to the underlying concepts. Previous research only describes these concepts and related characteristics in an isolated manner. Thus, we perform an inter-disciplinary structured literature review to relate and define the concepts of Service Systems, Smart Service Systems and Cyber-Physical Systems as well as related characteristics. This article can, therefore, serve as a basis for future research endeavors as it delivers a unified terminology.

Keywords: Service System, Smart Service System, Cyber-Physical System, literature review, conceptualization

1 Introduction

As businesses become interconnected, new opportunities and challenges arise for collaboration and co-creation [1, 2]. Different concepts, such as (Smart) Service Systems [3, 4] and Cyber-Physical Systems [5] emerge and strive to allocate, structure and explain phenomena in the field of digitally interconnected systems. However, these concepts are often used synonymously [4, 6] or contradict each other [5, 7]—which can lead to confusion and misunderstandings among practitioners and researchers. As a clear distinction of those concepts and related characteristics fosters the quality of future research, we aim to distinct Service Systems, Smart Service Systems and Cyber-Physical Systems. Thus, we ask the research question of *"How are the concepts Service System, Smart Service System and Cyber-Physical System defined and interrelated?"*. To approach this topic, we perform a structured literature research based on vom Brocke et al. [8] and Cooper [9] to identify commonly used definitions. We consolidate the insights and define each concept on this basis.

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Additionally, we aim to derive a conceptualization including the three concepts and ask the additional question: *"Which characteristics are mentioned in the context of the concepts?"*. By applying an open coding approach [10] on 110 identified articles from different disciplines defining the concepts, we identify several characteristics that are mentioned in literature and allocate them accordingly.

We aim to provide distinct definitions of these concepts in order to set a foundation for researchers and practitioners to understand the terms consistently. Based on this, we intend to overcome boundaries to other disciplines and allow for a common understanding as well as, accordingly, to accelerate new research and development in these areas.

The remainder of this article is structured as follows: First, we present theoretical foundations regarding socio-technical systems and system-of-systems. Second, we describe our methodology comprising a literature search followed by an open coding analysis of the identified concept definitions. Third, we analyze all three concepts in isolation and then summarize them through a conceptualization. Fourth, we present a discussion followed by a conclusion.

2 Theoretical Foundations

A system is generally referred to as a "collection of components organized to accomplish a specific function or set of functions" [11, p. 73]. Boulding [12] particularly stresses the system boundaries which delimit a system and determine which parts belong to a system and which to the environment. In an open system, interactions can take place with the environment, whereas in an isolated system no interactions can take place [11]. Interactions can be both the exchange of information (from an Information Systems (IS) viewpoint) [11] and the exchange of mass or energy (from a nature science viewpoint) [13]. Particularly complex open systems consisting of multiple parts that perform complex interactions with each other and with the environment are widely spread in reality [14].

In order to categorize (Smart) Service Systems and Cyber-Physical Systems and form a better understanding of these terminologies, the basic concepts *socio-technical systems* and *system-of-systems* are introduced.

2.1 Socio-technical Systems

The term socio-technical system is often used to describe complex systems consisting of several interacting components [15]. Originally, however, the term was used to describe a set of people and related technologies that are structured in a certain way to produce a specific result [16].

According to Cartelli [17], a socio-technical system consists of two components (subsystems): The technical subsystem represents assets such as machines and equipment, as well as processes and tasks that are responsible for the conversion of input resources into outputs. The social subsystem is made up of people (such as employees) who are structured in groups and have assigned certain roles to operate, control and use the components of the technical subcomponent. Cartelli emphasizes the facet of knowledge, which is “socially constructed and developed in the interactions among people” [17, p. 3], as part of the social subsystem and its value for a socio-technical system.

Both subsystems are “jointly independent, but correlative interacting” [16, p. 17] in order to pursue and adapt to goals in the socio-technical system’s environment and are therefore not separable from each other due to their manifold dependencies [15].

2.2 Systems-of-Systems

A system-of-systems has—like a typical system—interdependent components operating together to accomplish a certain common goal [18]. Unlike a typical system, the components of a system-of-systems are themselves systems [18]. According to Maier [19] a system-of-systems is an “assemblages of components that are themselves significantly complex, enough so that they may be regarded as systems and that are assembled into a larger system” [19, p. 269]. However, Maier names two limitations: First, the components must be operationally independent. That is, if a system-of-systems is broken down into its components, they must be able to fulfill their original purpose independently. Second, the component systems can not only work independently of each other, they do so as well. Thus, the subsystems maintain their operational independence continuously. Gideon et al. [18] summarize a system-of-systems as a “system build from independent systems that are managed separately from the larger system” [18, p. 357].

3 Methodology

With the foundations of socio-technical systems and systems-of-systems set, we elaborate on our applied methodology to reconstruct the state of the art of relevant literature. The scope of our literature review is systematized by the taxonomy proposed by vom Brocke et al. [8] and Cooper [9]. This taxonomy consists of six characteristics that distinguish literature reviews—focus, goal, organization, perspective, audience, and coverage—each including specific categories. Some of these categories are mutually exclusive, while for other characteristics several categories can be combined.

The focus of our literature research corresponds to the category research outcomes of the above-mentioned taxonomy. Furthermore, the goal of this article is the aggregation of already existing articles on the concepts Service System, Smart Service System and Cyber-Physical System—as well as their integration. The organization of this article is conceptually structured in order to aggregate the concepts separately. This article takes a neutral perspective. The target audience are scholars who are in need of a clear definition of the concepts as well as their distinction. To provide an appropriate overview of existing research, the literature search covers selected conferences and journals and, therefore, aims to be representative.

We conduct a systematic literature research according to vom Brocke et al. [8] in July 2018. While doing so, we focus on peer-reviewed articles from the field of

Information Systems, Service Science and Computer Science. In order to receive articles elaborating on (Smart) Service Systems and Cyber-Physical System, we use the search query: *"Service System" OR "Smart Service System" OR "Cyber Physical System"*. In a first step, we focus our search on the following selected Information Systems conferences and journals: International Conference on Information Systems (ICIS), European Conference on Information Systems (ECIS), Hawaii International Conference on System Sciences (HICSS), Information Systems Research (ISR), Information Systems Journal (ISJ), Management Information Systems Quarterly (MISQ), Journal of Management Information System (JMIS), European Journal of Information Systems (EJIS) and Business and Information Systems Engineering (BISE).

It is noticeable that the conferences have a much higher proportion of hits (ECIS: 21, ICIS: 14, HICSS: 10) in total than the journals (BISE: 8, MISQ: 2). The journals ISR, ISJ, JMIS and EJIS have no hits at all. In addition, it is recognizable that most of the hits date from the year 2018. Moreover, the number of hits has increased (Figure 1) over the years, which implies a strong relevance in terms of timeliness and strengthens the necessity for a clear nomenclature.

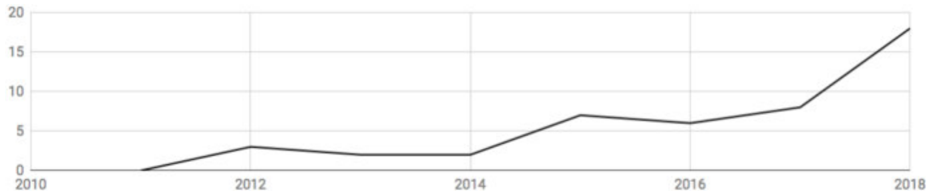

Figure 1. Number of hits in selected IS journals

When analyzing the outcomes, we noticed most of the articles relate to the concept of Service Systems, while in relatively few results the terms Smart Service System or Cyber-Physical System appear. Therefore, we extend our search across all disciplines using the literature database *Web of Science*. We realize that the term Service System plays a dominant role in the IS community, whereas the concept Cyber-Physical System occurs mainly in Computer Science literature. However, the term Smart Service System barely appears in the Web of Science database. Based on these findings, we conduct a Web of Science search for each of the three concepts separately and sort the results by number of citations and thereupon append the first 50 results for each concept to the literature list as well. In a third step, in addition, the outlets from the disciplines Service Science (six outlets with impact factor above 1[1]) and Computer Science (22 outlets with impact factor above 5[1]) are included as well. Thus, we ensure each of the communities in which the concepts are mainly used, are represented in this literature overview accordingly in a balanced manner.

Overall, the applied methodology results in an amount of 354 articles, which are selected by reading the abstract in order to exclude unrelated articles. Through forward

[1] The lower threshold for included outlet's impact factors is derived by the multiplication of the highest impact factor achieved in the specific discipline with a factor of 20 %

and backward search, further relevant articles are identified. By completely reading the remaining articles, all in all 110 relevant articles are selected and analyzed in a final step. All passages containing definitory statements with regard to at least one of the concepts is further analyzed by a coding approach to derive characteristics and interrelations of the considered concepts.

Within this subsequent step, two researchers analyze the concept definitions extracted from the articles using an open coding approach according to Saldaña [10]. With open coding we aim to find recurring characteristics of the individual concepts [10]. At the same time, we try to stay as open and unconstrained as possible in order to identify outstanding and particularly common characteristics from the literature. During this phase, we constantly compare all codes coded by two researchers as well as the underlying concept definitions to cluster passages that pertained to common codes. To substantiate our findings, we further integrate these common codes in order to derive more abstract conjoint categories and to harmonize different views.

4 Results

The results of the literature search and the analysis of the definitions depicted in each article are summarized in this section. In order to provide the reader with a comprehensive picture of the differences and similarities of the definitions, first the concepts are considered individually, before they are compared with each other.

4.1 Service Systems

The concept *Service System* appears most frequently in the results of our conducted literature search. Overall, 64 articles refer to the term Service System. According to Spohrer et al. [3] a Service System comprises *"service providers and service clients working together to coproduce value in complex value chains or networks"* [3, p. 72]. Components of a Service System are *"people, technology, internal and external service systems connected by value propositions, and shared information"* [3, p. 72] and examples include individuals, firms and nations. Based on this article from 2007, Maglio and Spohrer [20] synthesize the definition and formulate: *"Service systems are value-co-creation configurations of people, technology, value propositions connecting internal and external service systems, and shared information (e.g., language, laws, measures, and methods)"* [20, p. 18]. Examples include cities, businesses, nations, as well as individuals as the smallest representative of a service system and world economy as the largest [20].

The majority of articles adopt this definition [4, 7, 21–25], while others phrase it slightly different, but in principle remain faithful to the overall message [26–33]. Besides the more detailed definitions, some authors like Kleinschmidt and Peters [34] and Lintula et al. [35] use shorter and thus less specific descriptions. Böhmann et al. [36], Dörbecker and Böhmann [37] and Li and Peters [38] state that a Service System is a *"socio-technical system that enables value co-creation guided by a value* *proposition"* [36, p. 74], whereas Brust et al. [32] describe it as *"collections of people, technology and interactions"* [32, p. 8].

However, some authors deviate from this common definition and suggest divergent definitions, such as the one proposed in Höckmayr and Roth [39]: *"A service system is composed of multiple entities that interact to co-create value"* [39, p. 3]. Similarly, Motta et al. [40] differs from the common definition and describe a Service System only very abstract as a system which supports business services. Alter [41–44] refers to work systems and defines Service Systems as *"work systems that produce product/services and that may or may not involve co-production by customers and value co-creation"* [41, p. 4], while a work system is a *"system in which human participants and/or machines perform work using information, technology, and other resources to produce products and services for internal or external customers"* [41, p. 4]. Although some authors like Blohm et al. [45], Dörbecker et al. [46] and Matzner and Scholta [47] use the term Service System and name components as well as properties, but avoid defining it.

In conclusion, we also suggest using the definition according to Maglio and Spohrer [20] and Spohrer et al. [3], as it is the most concise and commonly used one, and define Service Systems for this article as *"value-co-creation configurations of people, technology, value propositions connecting internal and external service systems, and shared information (e.g., language, laws, measures, and methods)"* [20, p. 18].

4.2 Smart Service Systems

The concept *Smart Service System* has the lowest number of hits with only 10 represented articles in the searched outlets and databases. This concept is described by Barile and Polese [7], Maglio [4] and Medina-Borja [48] as an extension of the Service System concept containing self-management capabilities. Barile and Polese [7] define: *"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"* [7, p. 31].

According to Maglio [4], Smart Service Systems are *"capable of self-detection, self-diagnostic, self-corrective, or self-controlled functions through the incorporation of technologies for sensing, actuation, coordination, communication, control, and more"* [4, p. 1]. By automating and self-managing systems, high costs and security risks caused by humans can be reduced, which can lead to improved offers or even new ones [4].

Beverungen et al. [49] state that Smart Service Systems are Service Systems, *"in which smart products are boundary-objects that integrate resources and activities of the involved actors for mutual benefit"* [49, p. 6].

According to the authors Maglio and Lim [50] as well as Medina-Borja [48], such a system is even *"capable of learning, dynamic adaptation, and decision making based upon data received, transmitted, and/or processed to improve its response to a future situation"* [50, p. 2], which can be done by integration of sensing, actuation and communication technologies. In addition, Maglio and Lim [50] describe that big data analytics can contribute to the innovation of Smart Service Systems by *"embedding human knowledge and capabilities in technologies to serve human purposes for effective value co-creation"* [50, p. 3]. Santo et al. [51] also emphasize the capability of such a system to learn and to *"simultaneously optimizing the use of resources and improving the quality of the services provided"* [51, p. 3].

Nevertheless, we recommend using a modification of the definition proposed by Medina-Borja [48] as it is the most detailed and comprehensive and includes most of the characteristics of the other definitions. Furthermore, it delivers a clear demarcation from Service Systems: *"A 'smart' service system is a [Service] [S]ystem capable of learning, dynamic adaptation, and decision making based upon data received, transmitted, and/or processed to improve its response to a future situation. The system does so through self-detection, self-diagnosing, self-correcting, self-monitoring, self-organizing, self-replicating, or self-controlled functions. These capabilities are the result of the incorporation of technologies for sensing, actuation, coordination, communication, control, etc."* [48, p. 3].

4.3 Cyber-Physical Systems

Hauser et al. [52] state that research on *Cyber-Physical Systems (CPS)* no longer takes place only in the disciplines of electronics and computer science, but also extends to other fields such as IS. Therefore, they describe a CPS as the extension of a legacy system with information technology [52]. Similarly abstract is the definition of Banerjee et al. [53], who describe CPS as *"systems that use the information from the physical environment, and in turn affect the physical environment"* [53, p. 283]. Furthermore, they list examples such as smart electricity grid and unmanned aerial vehicles [53]. Likewise, Gölzer et al. [6] argue that CPS are *"able to communicate with each other, to detect their environment, to interpret available data and to act on the physical world"* [6, p. 1]. They also emphasize the capabilities of self-control and self-optimization [6], while Gruettner et al. [54] describe CPS as *"intelligent networking of people, machines, and industrial processes, which in product components communicate with the production gear by embedded sensors"* [54, p. 1853].

Bradley and Atkins [55] state that CPS *"interface physics-based and digital world models"* [55, p. 60] and emphasize the benefits of integrating physical and computational models.

A formal definition is provided by Burmester et al. [56] describing a CPS as a *"finite state system consisting of several networked components, some of which may be cyber while others are physical"* [56, p. 3].

Akkaya et al. [57] identify the challenges of designing a Cyber-Physical System as *"complexity, heterogeneity, and multidisciplinary nature"* [57, p. 997], but avoid using a distinct definition. In addition, there are some articles that use the term CPS, but neither describe nor define it [58–62]. Other authors give examples such as smart grids [63, 64], Machine-to-Machine communication [65] and data centers [66], but also avoid clear definitions. However, most authors describe CPS basically as a conjunction of computation and physical processes, where there is a mutual influence through observation and control [67–73].

Böhmann et al. [36] build the bridge to Service Systems and explain that the availability of data and automation capabilities provided by Cyber-Physical Systems contribute to Service System innovation. Matzner and Scholta [47] also combine the CPS and Service Systems concepts and define: *"[CPS] are service systems that connect physical and cyber elements through global networks"* [47, p. 0].

Furthermore, Gunes et al. [5] summarize some aspects of different definitions and define CPS as *"complex, multi-disciplinary, physically-aware next generation engineered systems that integrate embedded computing technology (cyberpart) into the physical phenomena"* [5, p. 4244], where integration is achieved by the capabilities of *"observation, communication, and control [...] of the physical system"* [5, p. 4244].

Sanislav and Miclea [74] also recognize the variety of different definitions provided in the existing literature and list several, however, without synthesizing or providing their own.

Ribeiro et al. [75] and Wu et al. [73] emphasize the intelligence of such systems and characterize CPS as *"intelligent systems that are composed of digital virtual/cyber technologies, software, and physical components, and intelligently interact with other systems across information and physical interfaces"* [75, p. 6131]. Sampigethaya and Poovendran [76] consider CPS based on applications in aviation and describe mainly benefits and challenges. Also Sztipanovits et al. [77] and Yao et al. [78] focus mainly on challenges related to the integration of the various computational and physical elements of CPS.

Furthermore, Wan et al. [79] describe some characteristics of CPS such as *"cyber capability in every physical component*" [79, p. 1108], *close integration*, *"dynamically reorganizing/reconfiguring"* [79, p. 1108], and *"high degrees of automation"* [79, p. 1108].

We recommend following the definition of the majority of the authors and, thus, we provide an abstract definition: *"A Cyber-Physical System is an intelligent system connecting the physical and the digital/cyber world through influence and control using sensors and actuators"*.

4.4 Summary

This literature review shows that the concepts Service System, Smart Service System and Cyber-Physical System are not uniformly defined and also that the differentiation is not always clear. While most authors agree on Service Systems, Smart Service Systems and CPS in particular are not clearly defined.

By applying an open coding approach, properties of the examined concepts described in the articles are codified. Codes with similar characteristics are clustered and, thus, grouped together in categories [10]. Overall, we identify five categories of properties the concepts Service System, Smart Service System and Cyber-Physical System have in common. Table 1 depicts five identified categories components, attributes, actions, structure and boundaries. The categories components, attributes, and actions include a set of codes resulting from the different views of the articles being analyzed. We consider the most frequently occurring representatives for these three categories.

Table 1. Conceptualization of (Smart) Service Systems and Cyber-Physical Systems

	Service System	*Smart Service System*	*Cyber-Physical System*
key components	information, people, technology	data, people, technology	cyber part, sensors, actuators
key attributes	interaction, dynamic, adaptive	interaction, adaptive, learning, decision-making	interaction, intelligent, distributed
key actions	value creation	sensing, control	sensing, control
structure	complex, people-centered	complex, self-centered	complex, data-centered
boundaries	open, dynamic	open, dynamic	open, partially dynamic

The key components of all three concepts are frequently mentioned in the definitions within the articles and are also conceptually very clear, especially in the concepts of Service System and Smart Service System. For example, Service Systems and Smart Service systems both include *people* and *technology*, while in terms of Service Systems, the term *information* is very present, data is often referred to in Smart Service Systems. A CPS consists of a *cyber part* that provides computational capabilities, *sensors* collecting data, as well as *actuators*.

A variety of attributes are mentioned across all analyzed articles, however, only the key attributes are listed in Table 1. All three concepts emphasize the *interaction* between components, but also the interaction with the environment. Likewise, the attribute *adaptability* appears for all three concepts, although it is not mentioned as often in CPS definitions as the attribute *distributed*. In addition, the code *dynamic* is very common in Service Systems, while a CPS is particularly described as *intelligent* and Smart Service Systems is capable to *learn* and *make decisions*.

However, a small number of key actions are named, but the ones named are mentioned very frequently. Nearly every article defining a Service System names the goal of *creating value*. For Smart Service Systems and CPS, the actions are not quite as clean, but for both the two most common are *sensing* and *control*.

The structure of all three analyzed systems is described as a complex. In addition, Service Systems focus on people—both as component and user—while Smart Service Systems focus on the system itself and its purpose. CPS are often outlined as data-centered.

All three concepts are considered to be *open* systems. Furthermore, Service Systems and Smart Service Systems are able to change *dynamically*, while for CPS at least the physical part is fixed, but the components of the cyber part can also change dynamically.

5 Discussion

The analysis of the literature on the three concepts shows that Service Systems can be understood as socio-technical systems [29, 36–38, 48, 80]. In addition, a Smart Service Systems is a special kind of a Service System [7, 33, 50, 81]. CPSs, on the other hand, are referred to as a kind of Service System [47], but more often characterized as technical systems [5, 31, 82–84], which can thus be part of a socio-technical and, thus, part of a (Smart) Service System.

The analysis also shows that the need for information in Service Systems is enormous as it acts as a key component. The same applies to data in Smart Service Systems. This data, which can be further processed into information, can be collected by CPS. Thus, by enriching CPS with connectivity capabilities, the need for information / data of (Smart) Service Systems can be met. In addition, intelligent CPS can also serve as a social component to mimic the role of people.

Thus, the concepts Service System, Smart Service System and CPS are closely interlinked and, therefore, have similar characteristics. All concepts emphasize the interaction between humans and technology and the ability for multi-criteria decision-making. This leads to extremely complex and heterogeneous structures that can dynamically adapt over time.

In addition to components such as humans, technology or CPS, however, Service Systems themselves can also be components of Service Systems. This system-of-system property affects all three concepts. Thus, the system boundaries can be extended by parts of the environment, so that other systems arise.

Figure 2 depicts the interrelations of the three considered concepts as well as their connections to socio-technical system and system-of-systems concepts.

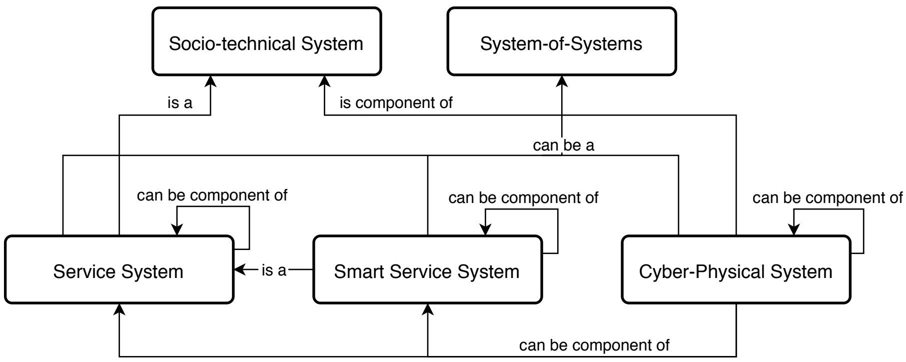

Figure 2. Interrelations of (Smart) Service Systems and Cyber-Physical Systems

6 Conclusion

The concepts of (Smart) Service Systems and Cyber-Physical Systems has been a re-occurring term in research and industry. Aiming for precise definitions, distinctions and similarities, we apply a thorough literature research and review 110 relevant articles. As a result, we show that especially the concepts Smart Service System and Cyber-Physical System are often used in a similar context in different disciplines. The concepts include similar facets and characteristics. However, our research reveals some cases of inconsistent definitions, especially for the concepts of Smart Service Systems and Cyber-Physical Systems. For clarification, we derive suitable definitions from literature and fuse them in a conceptualization. These definitions and concepts may assist researchers in the understanding of the terms and their relationships.

Our work is limited to literature originating mainly from the fields of Information Systems, Service Science and Computer Science community. Furthermore, it can remain subjective as to whether a definition is more suitable than another to understand broader concepts. To address this, we based our research on occurrences in related articles, but cannot account for all articles across all disciplines. Moreover, the identified characteristics are not validated concerning their completeness and meaning within different disciplines. In total, this work sets a foundation for researchers and practitioners to understand the concepts consistently and, accordingly, to push for new research and development in these areas with the same terminology in mind to avoid misunderstandings.

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