Technical Report - DIAB-21-11-1

Models for IoT related paradigms

Aurora Macías Ojeda and Elena Navarro

LoUISE Research Group, University of Castilla-La Mancha, 02071 Albacete, Spain

Aurora.Macias@alu.uclm.es and Elena.Navarro

A Thematic Synthesis has been conducted to analyse the IoT paradigms. Here the different models are presented as directed graphs whose nodes are themes, and its edges are labelled describing the relationships among the connected themes. Thus, by reading the graphs presented in Appendix A, the relationship among the themes can be observed to draw conclusions about the descriptions and definitions of the IoT-related paradigms. This also facilitates highlighting the differences among the paradigms. In each graph, a star shape node will be used to identify the IoT related paradigm being analyzed, shaded nodes will describe higher-order themes, and white background nodes will be used for second- or third-order themes.

Moreover, the analysis of different proposals regarding the model created is presented in Appendix B.

Appendix A. Model for the paradigms

A.1. Principles and Technological Aspects

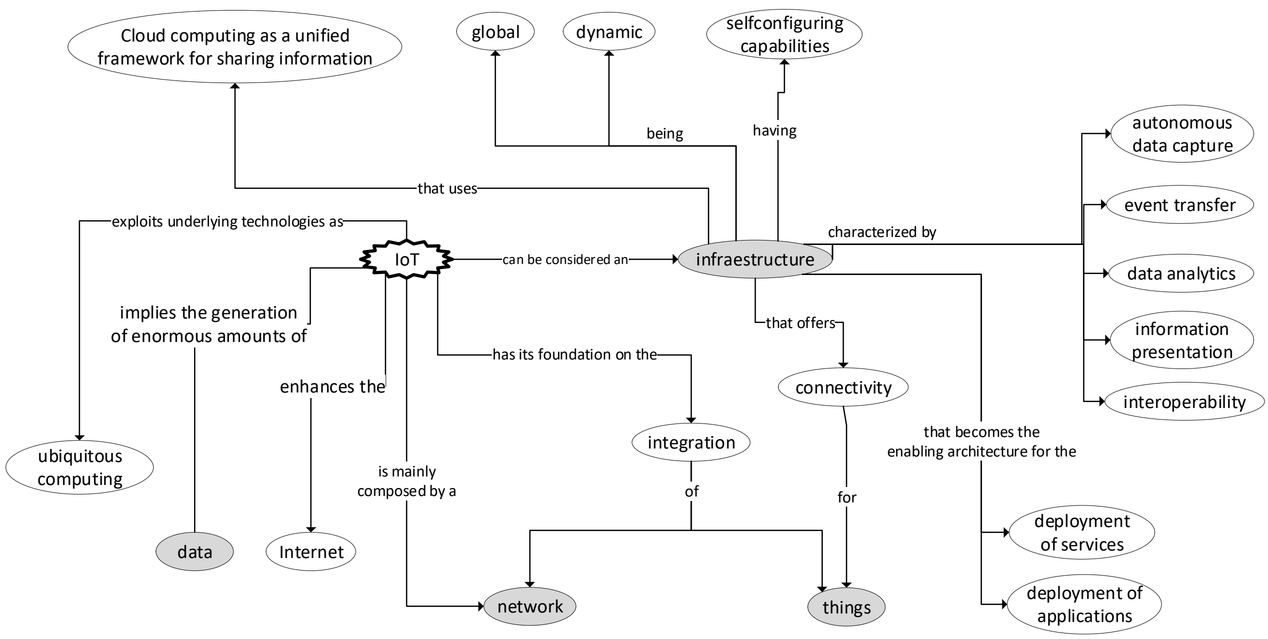

Figure 1. Technological aspects and principles graph for IoT

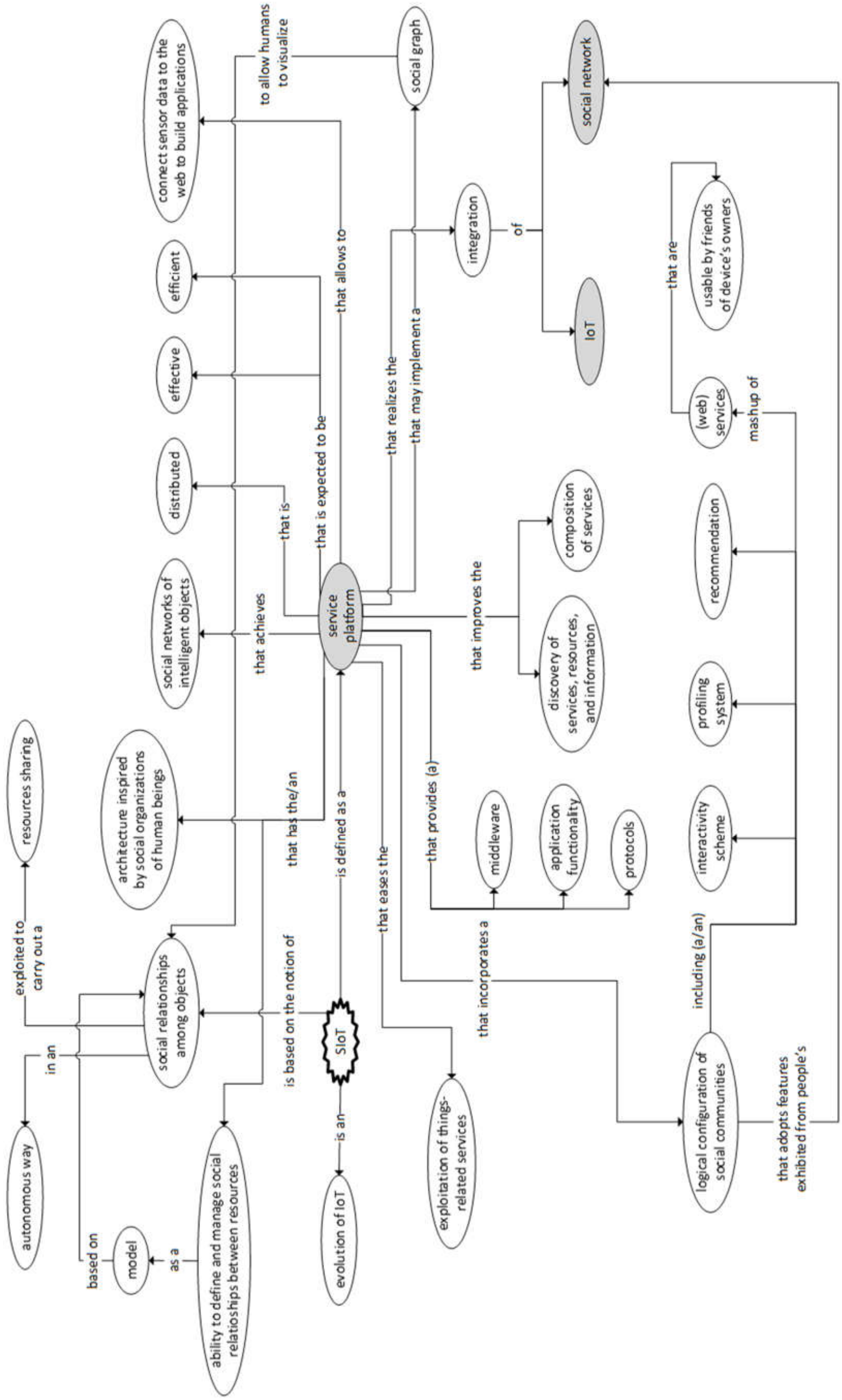

Figure 2. Technological aspects and principles graph for SIoT

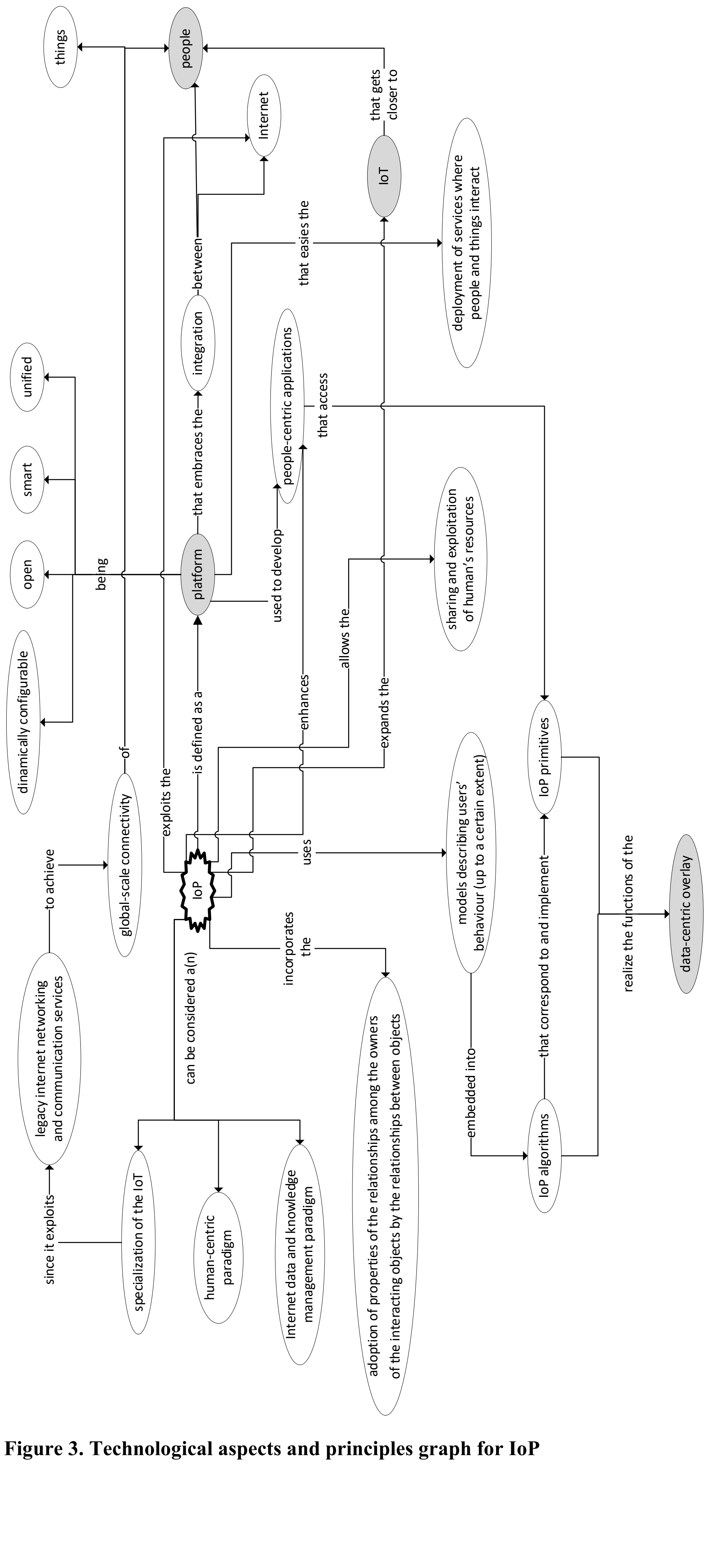

Figure 3. Technological aspects and principles graph for IoP

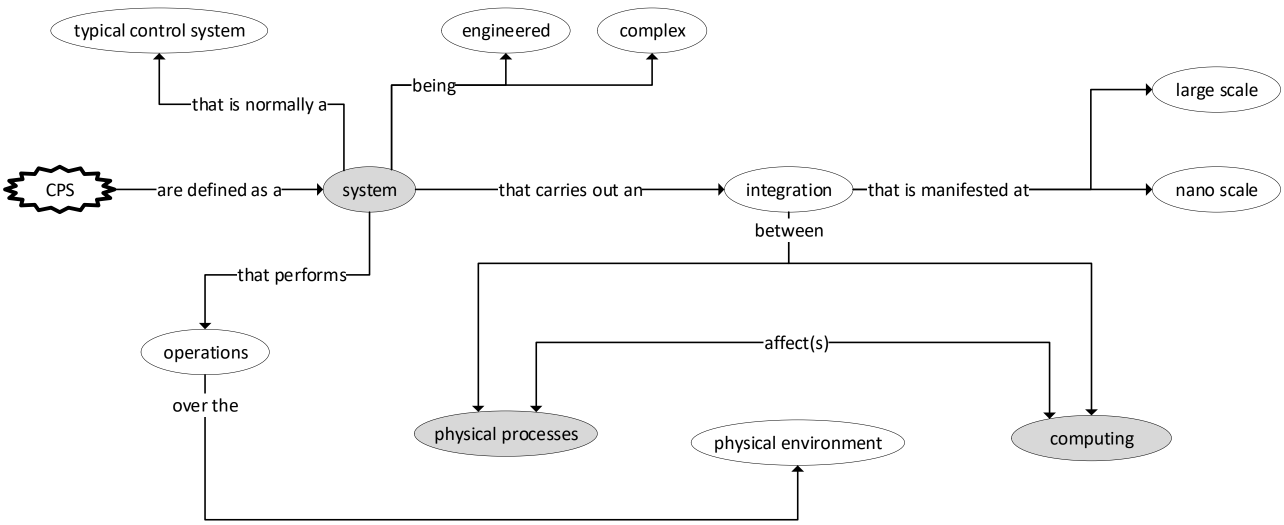

Figure 4. Technological aspects and principles graph for CPS

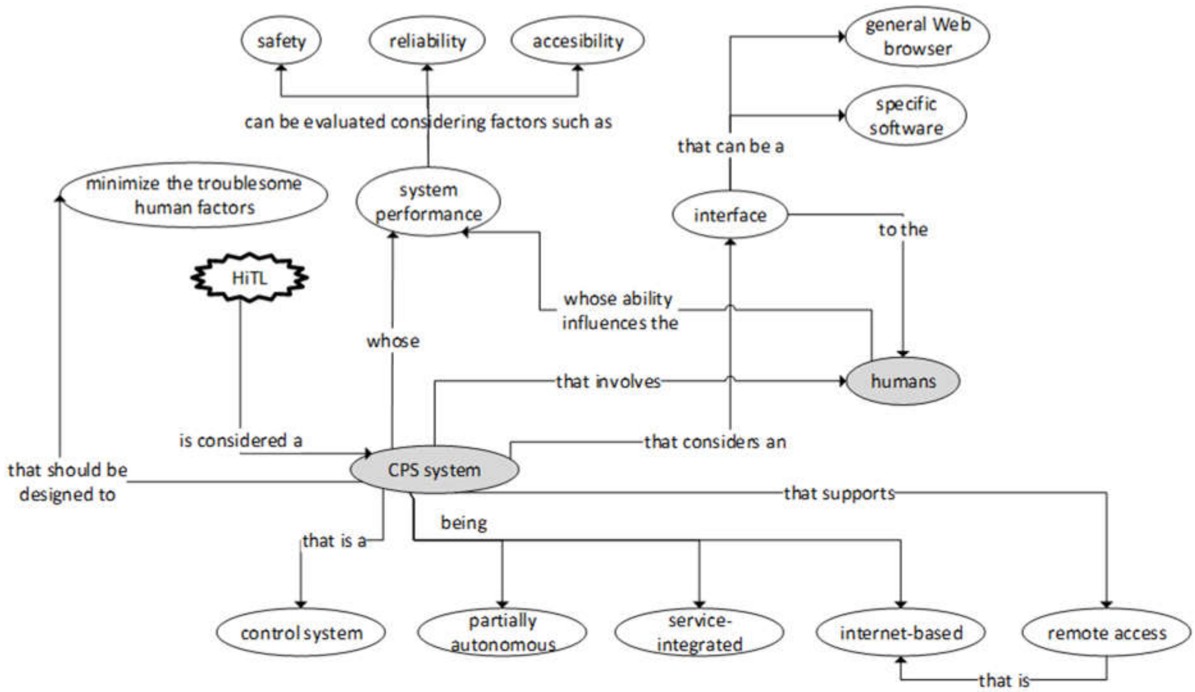

Figure 5. Technological aspects and principles graph for HiTL

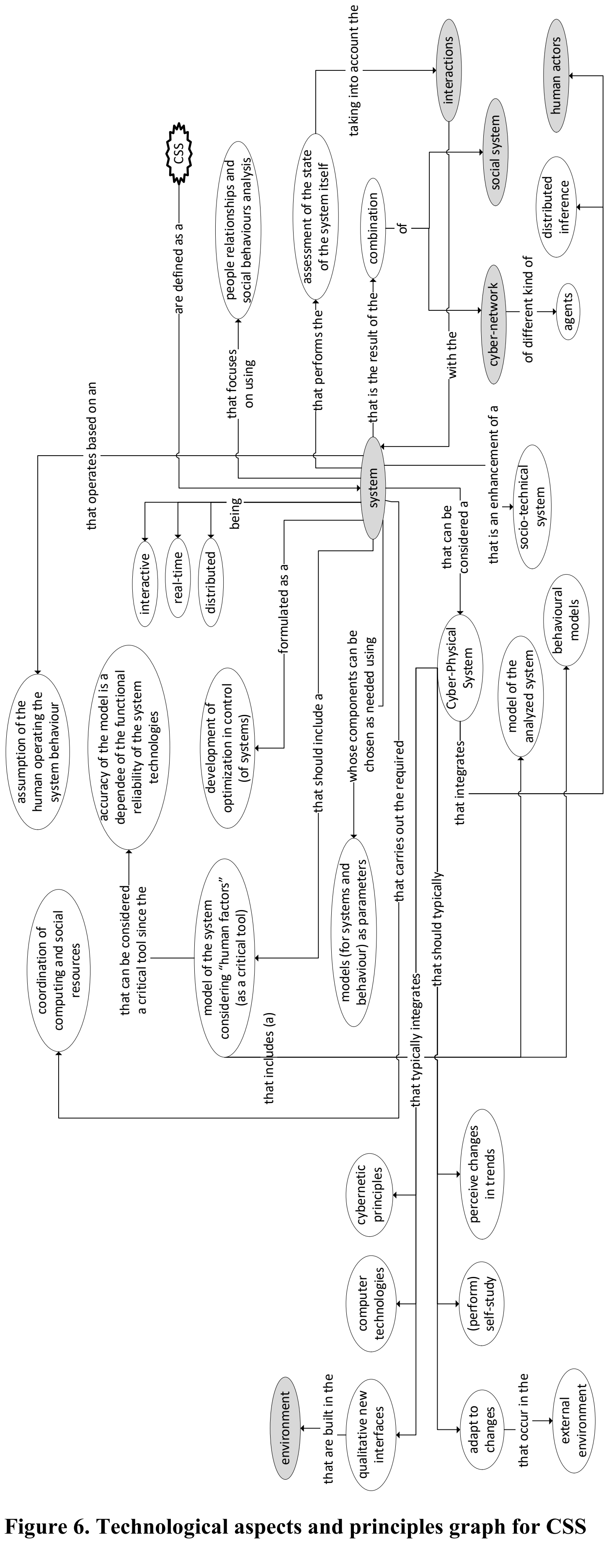

Figure 6. Technological aspects and principles graph for CSS

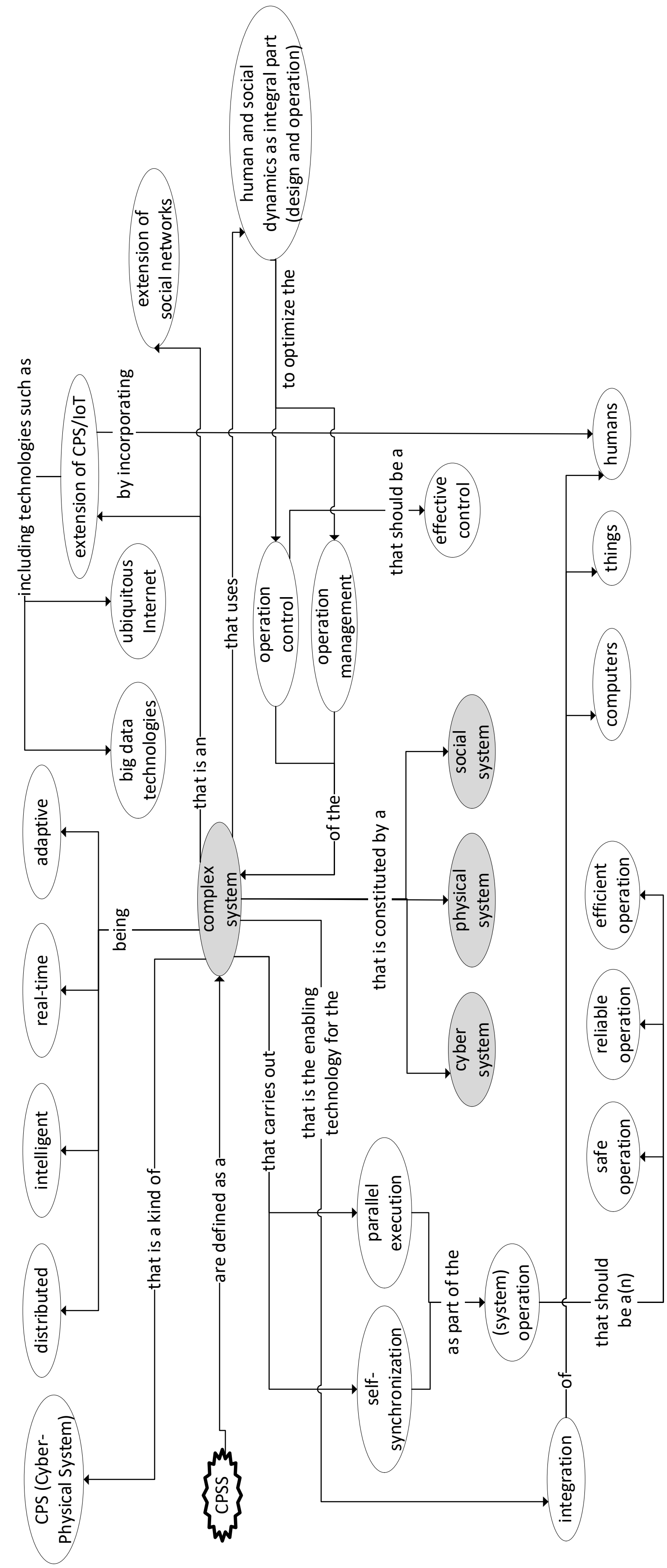

Figure 7. Technological aspects and principles graph for CPSS

A.2. Main components

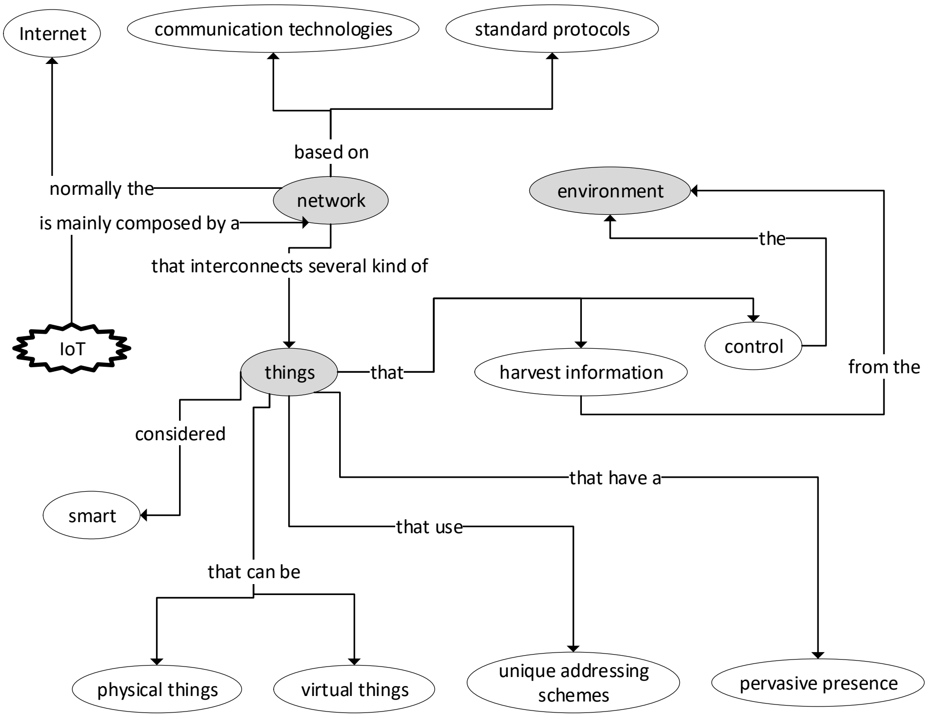

Figure 8. Subsystems and main components graph for IoT

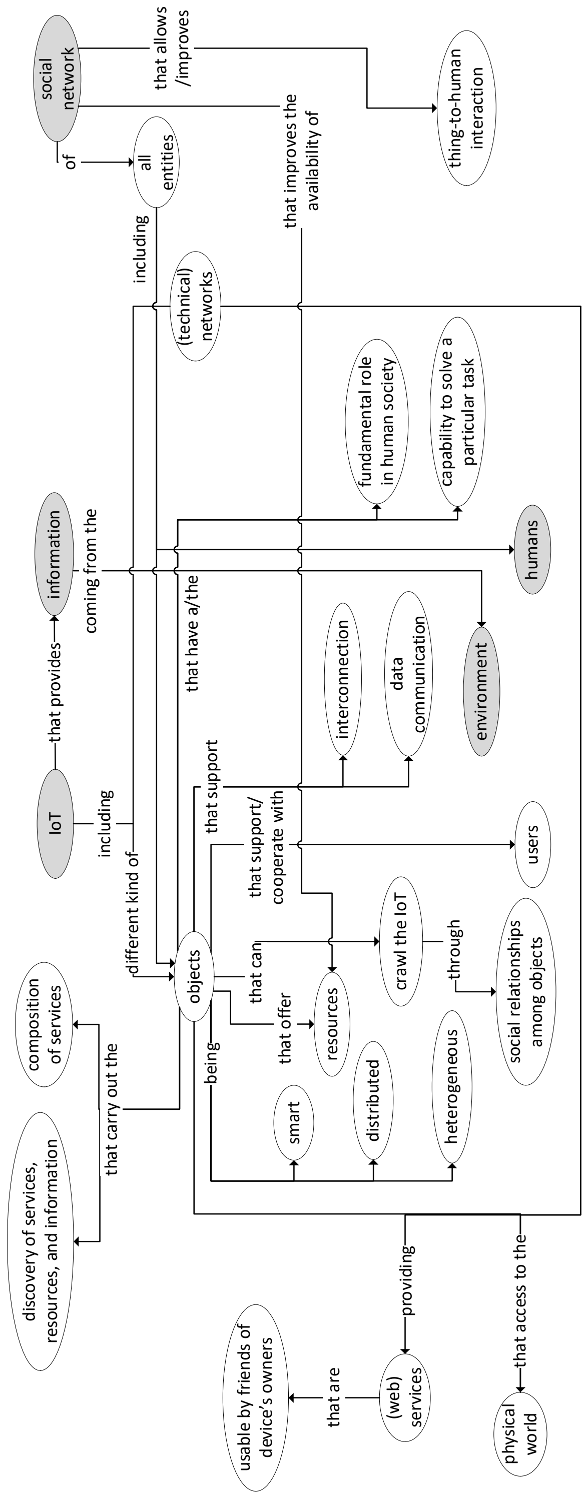

Figure 9. Subsystems and main components graph for SIoT

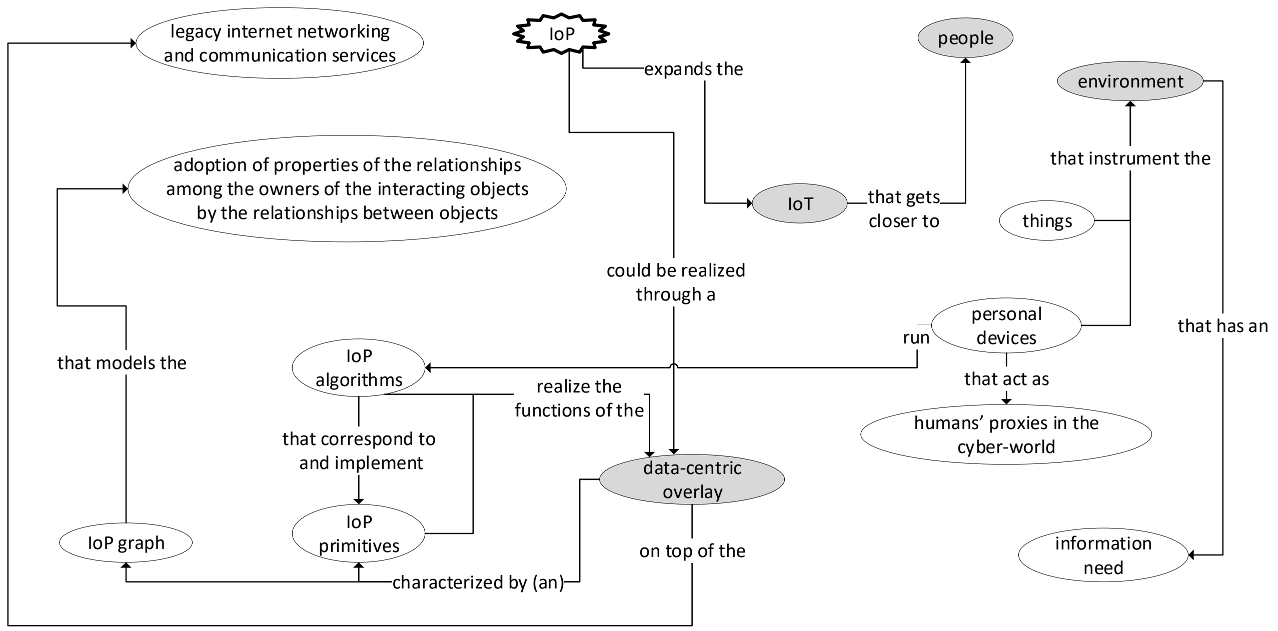

Figure 10. Subsystems and main components graph for IoP

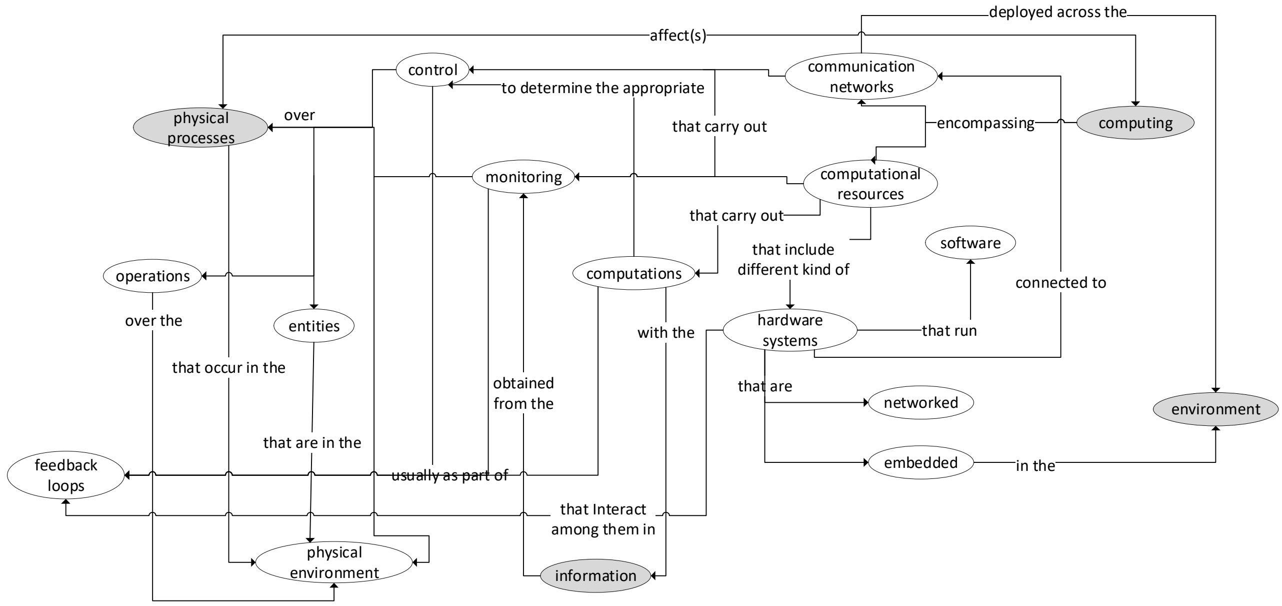

Figure 11. Subsystems and main components graph for CPS

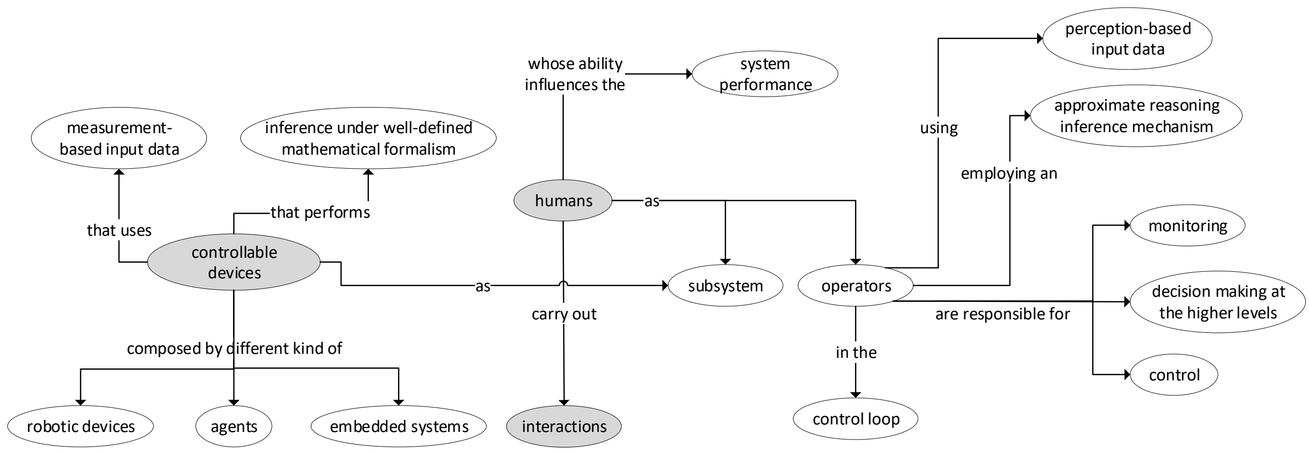

Figure 12. Subsystems and main components graph for HiTL

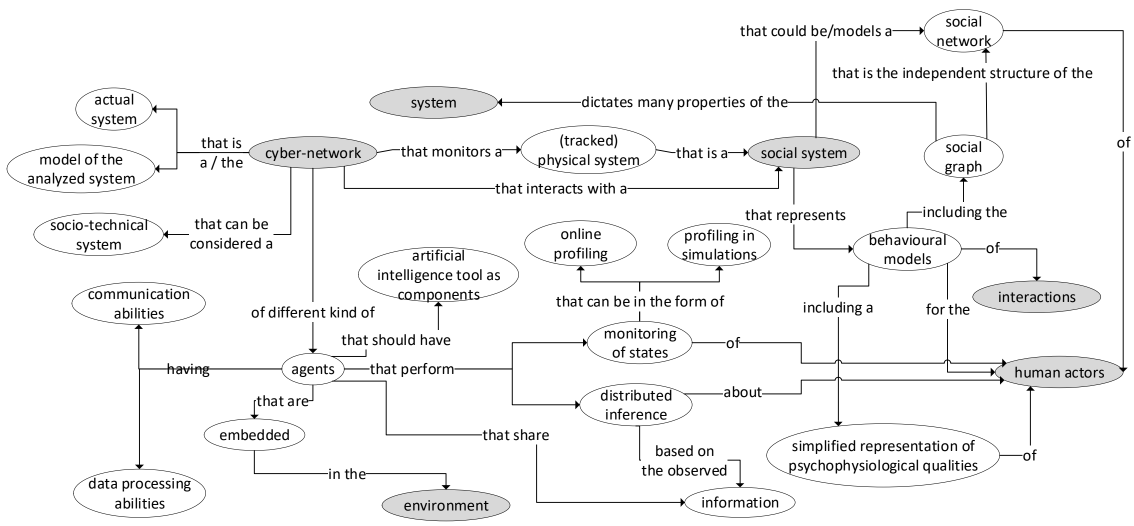

Figure 13. Subsystems and main components graph for CSS

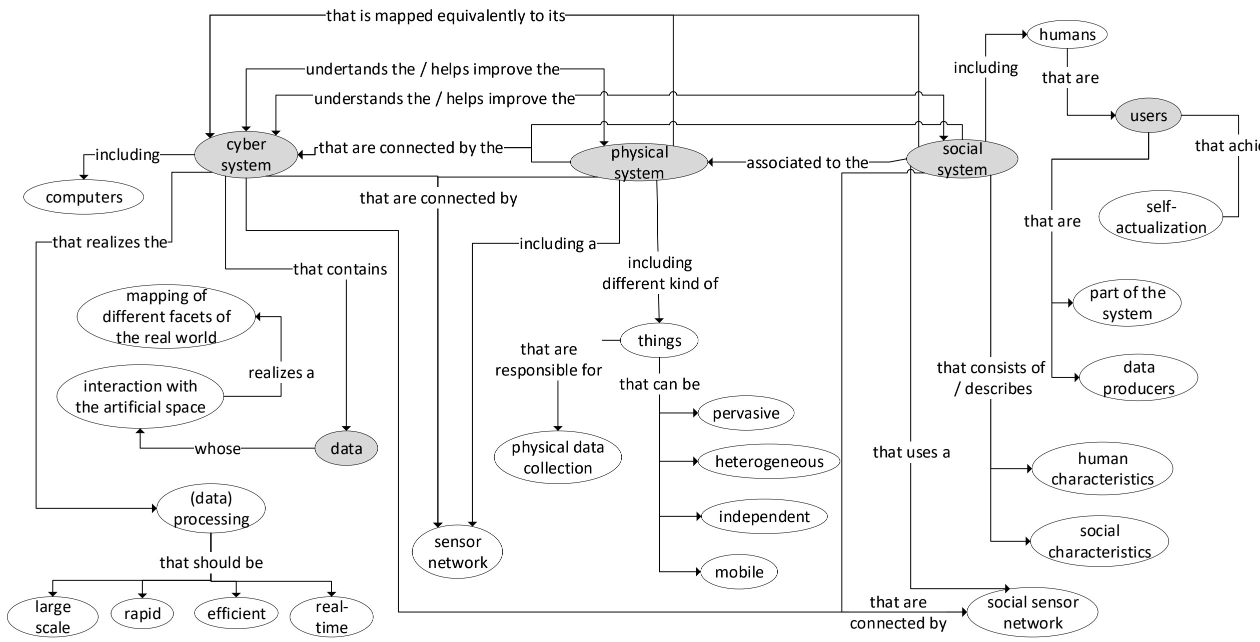

Figure 14. Subsystems and main components graph for CPSS

A.3. Environments

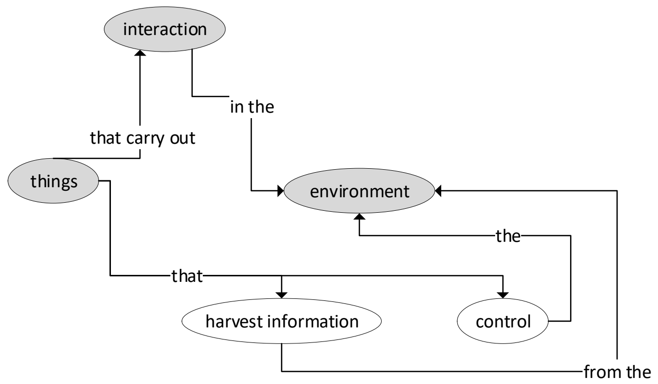

Figure 15. Environment graph for IoT

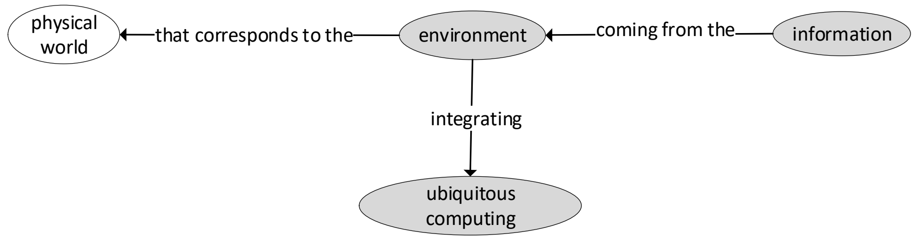

Figure 16. Environment graph for SIoT

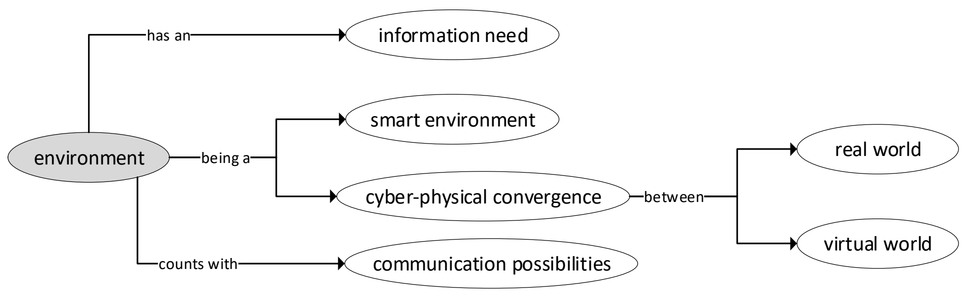

Figure 17. Environment graph for IoP

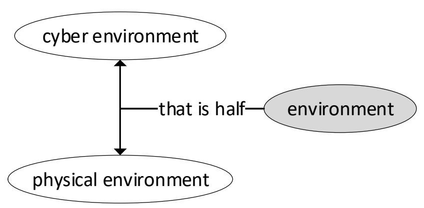

Figure 18. Environment graph for CPS

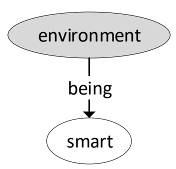

Figure 19. Environment graph for HiTL

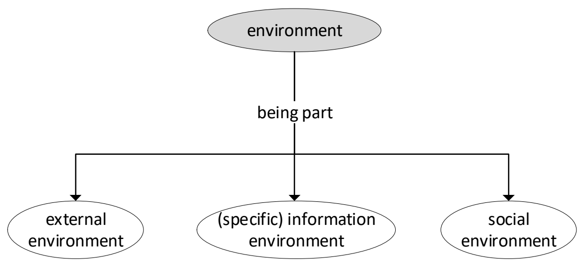

Figure 20. Environment graph for CSS

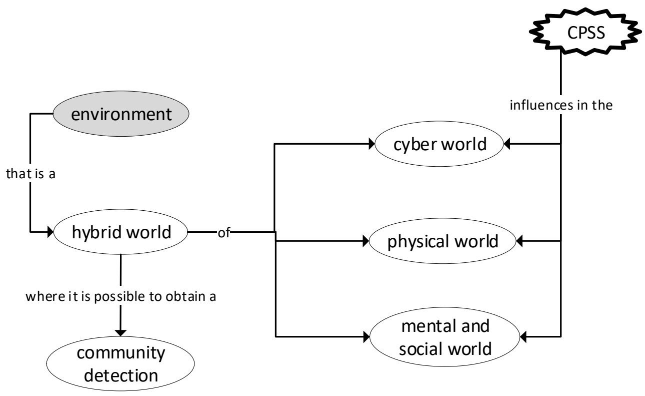

Figure 21. Environment graph for CPSS

A.4. Humans/Users

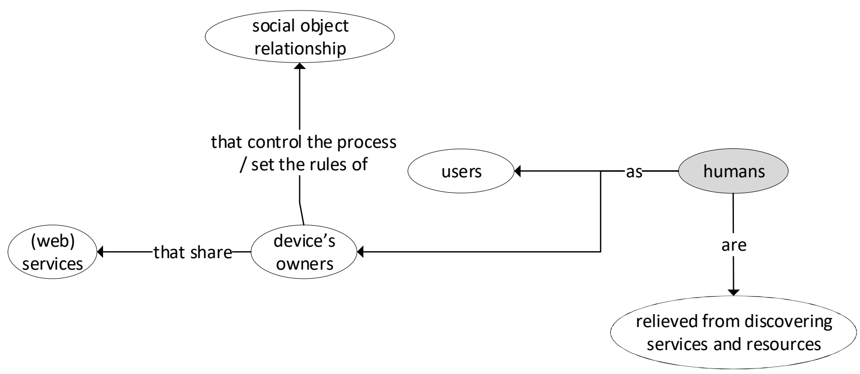

Figure 22. Humans/users graph for SIoT

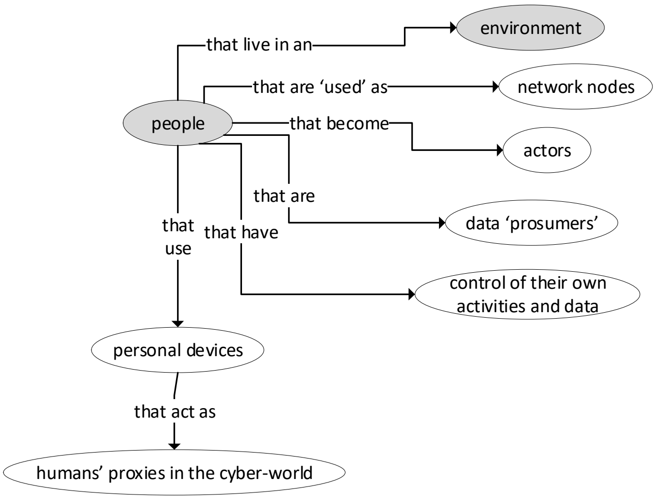

Figure 23. Humans/users graph for IoP

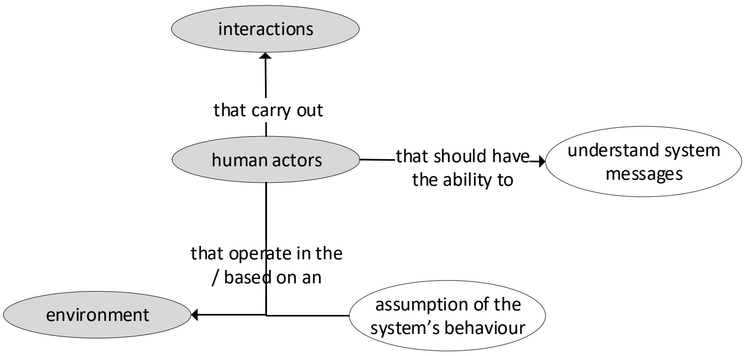

Figure 24. Humans/users graph for CSS

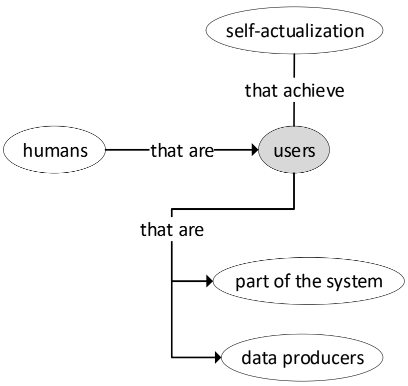

Figure 25. Humans/users graph for CPSS

A.5. Interaction

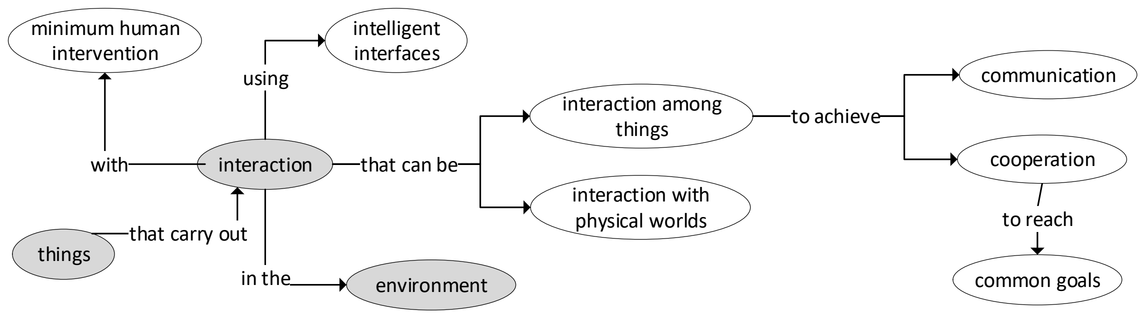

Figure 26. Interaction graph for IoT

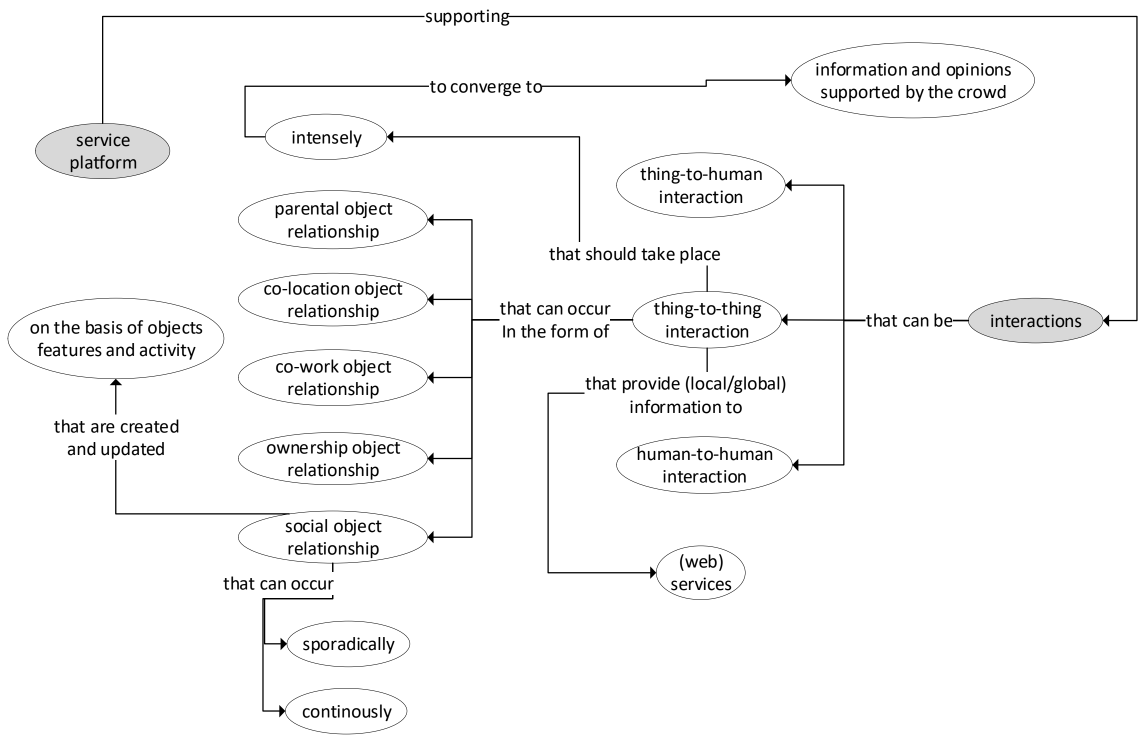

Figure 27. Interaction graph for SIoT

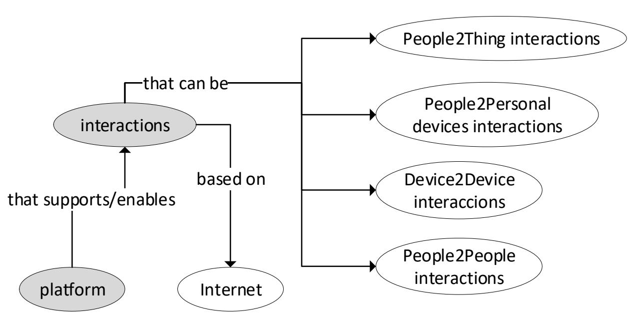

Figure 28. Interaction graph for IoP

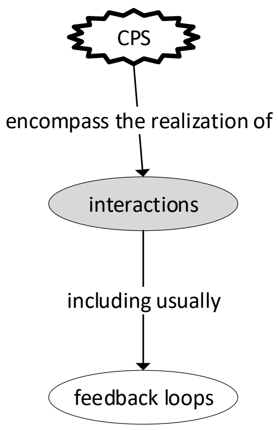

Figure 29. Interaction graph for CPS

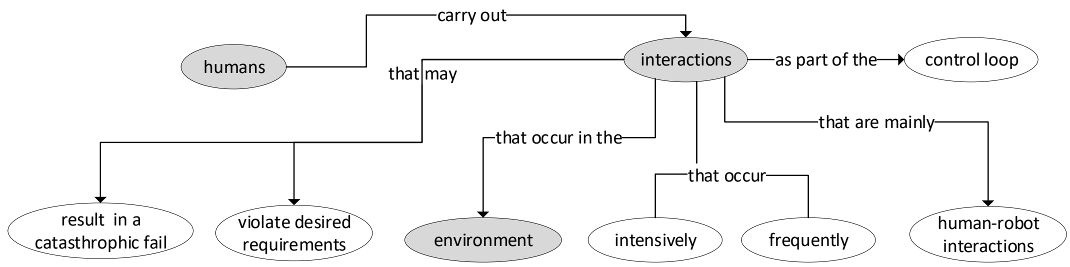

Figure 30. Interaction graph for HiTL

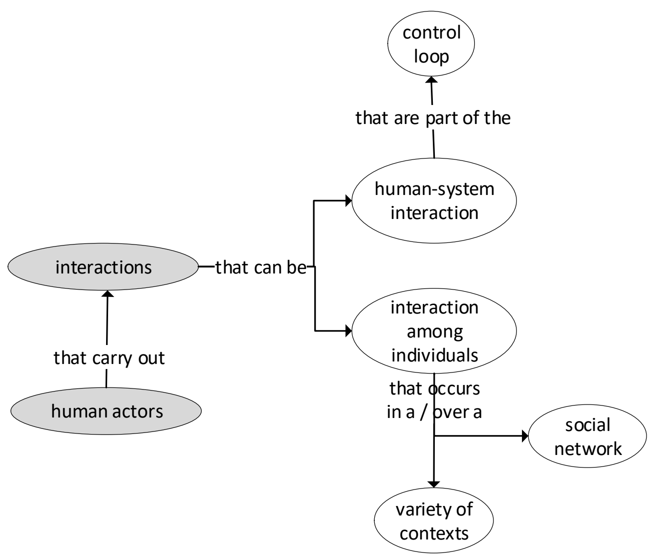

Figure 31. Interaction graph for CSS

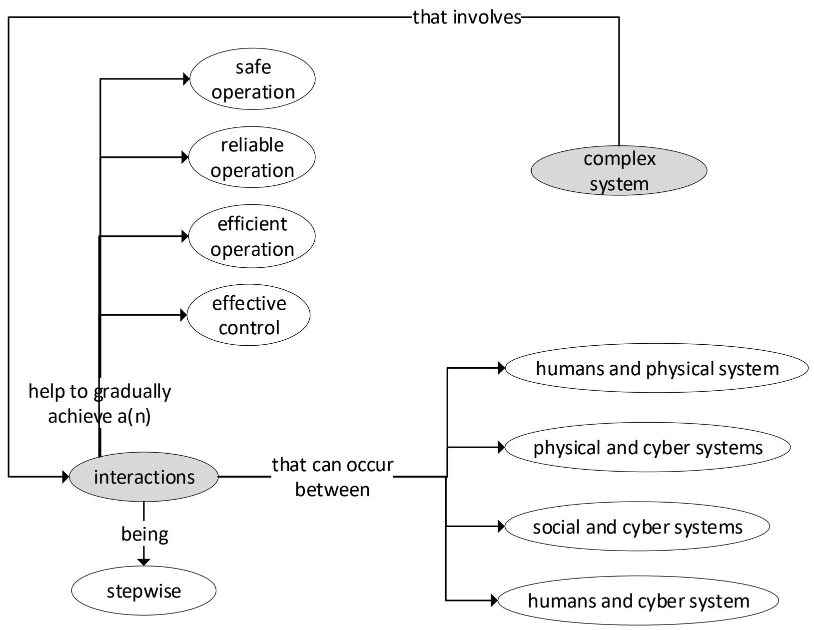

Figure 32. Interaction graph for CPSS

A.6. Information

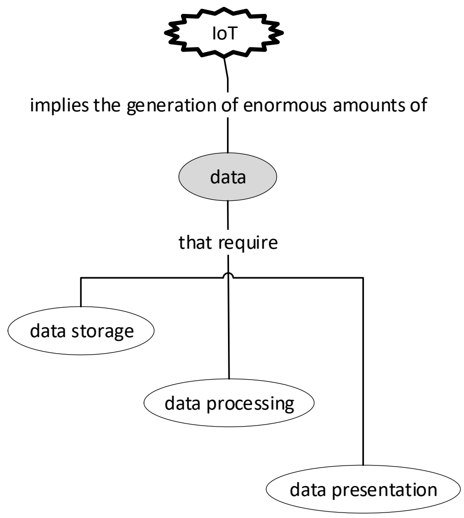

Figure 33. Information graph for IoT

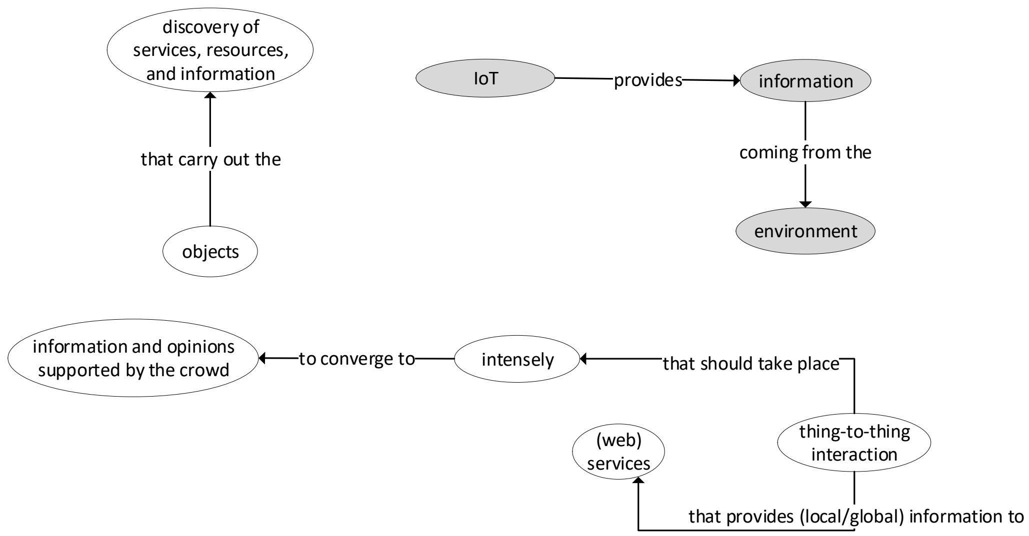

Figure 34. Information graph for SIoT

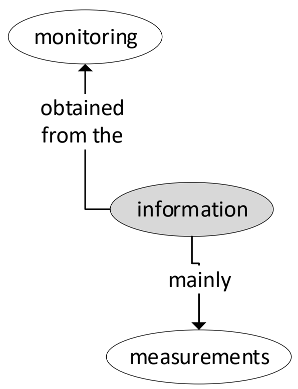

Figure 35. Information graph for CPS

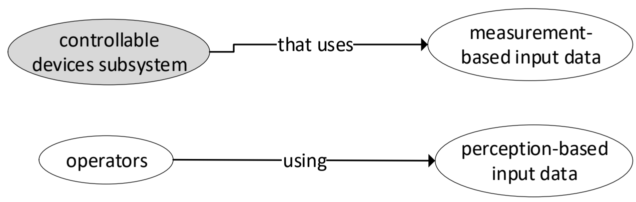

Figure 36. Information graph for HiTL

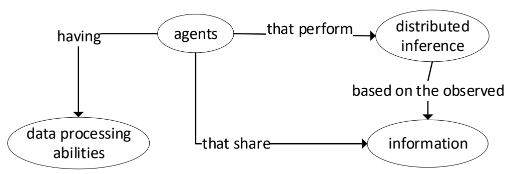

Figure 37. Information graph for CSS

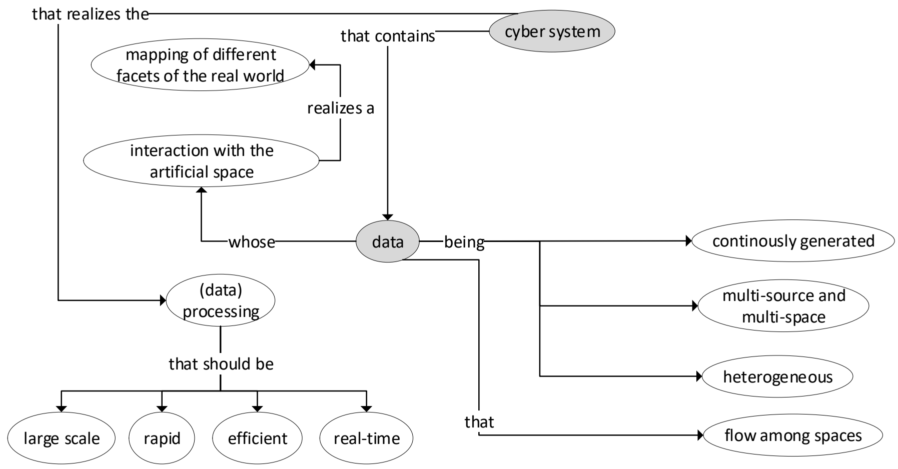

Figure 38. Information graph for CPSS

A.7. Benefits

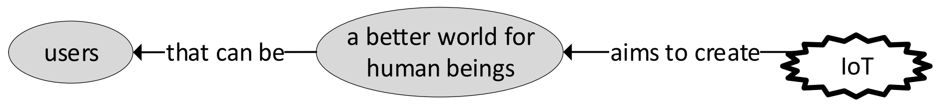

Figure 39. Benefits graph for IoT

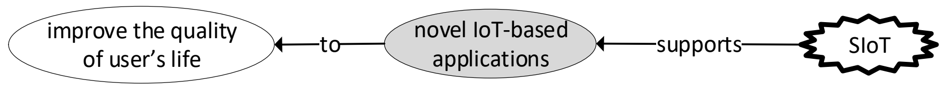

Figure 40. Benefits graph for SIoT

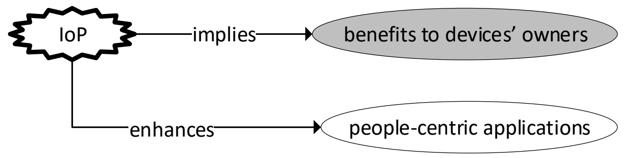

Figure 41. Benefits graph for IoP

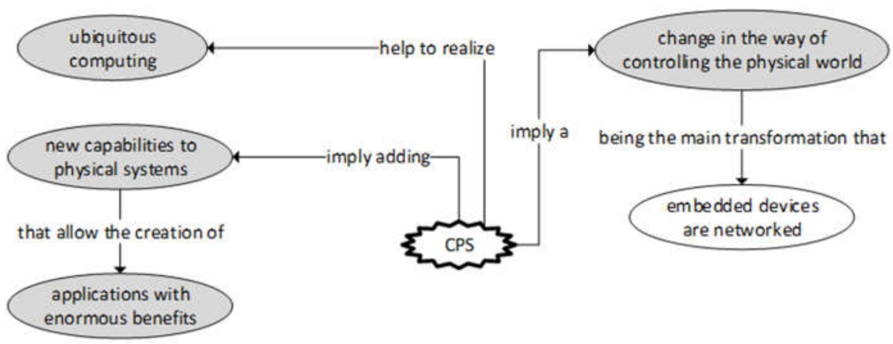

Figure 42. Benefits graph for CPS

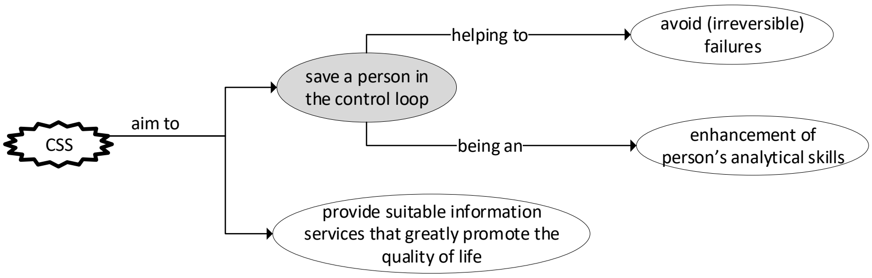

Figure 43. Benefits graph for CSS

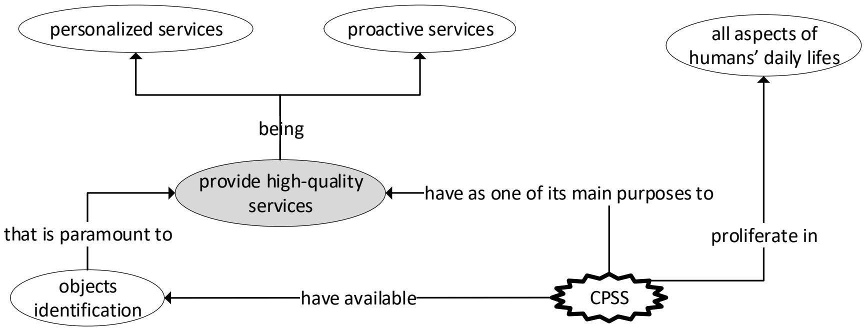

Figure 44. Benefits graph for CPSS

A.8. Related computing paradigm(s)

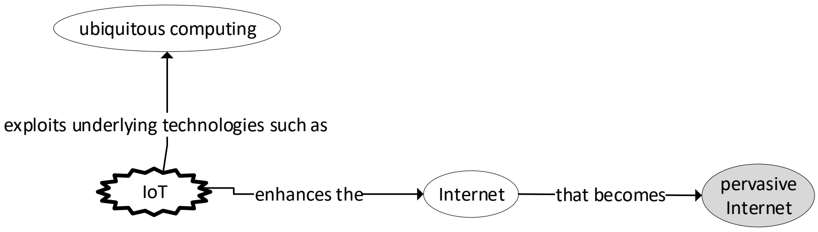

Figure 45. Related computing paradigm(s) graph for IoT

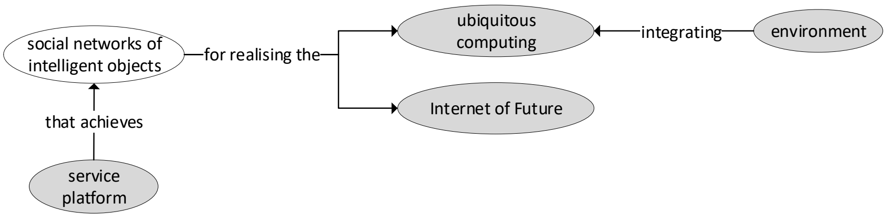

Figure 46. Related computing paradigm(s) graph for SIoT

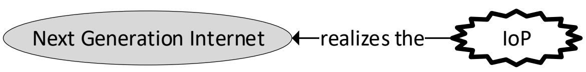

Figure 47. Related computing paradigm(s) graph for IoP

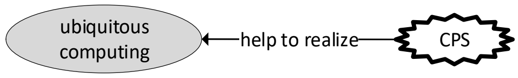

Figure 48. Related computing paradigm(s) graph for CPS

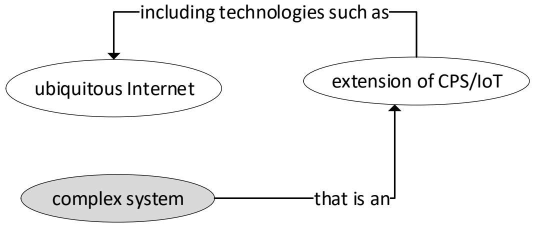

Figure 49. Related computing paradigm(s) graph for CPSS

Appendix B

Table 1. IoT-related developments application examples reclassified

ID	Example description	Originally classified as	Model aspects identified	Reclassified as
1	Urban noise pollution monitoring and analysis system based on an IoT infrastructure (Jin et al. 2014).	IoT	Global and dynamic infrastructure that includes a network, the Internet, that interconnects several kind of things (see Figure 8). Things, considered smart, are physical (sensors) and virtual (relay nodes), have a pervasive presence, and harvest information from the environment (see Figure 8). The infrastructure uses cloud computing as a unified framework for sharing information (see Figure 1). This infrastructure is characterized by facilitating autonomous data capture, event transfer, data analytics, information presentation, and interoperability (see Figure 1).	-
2	Healthcare monitoring system with Electrocardiogram (ECG) feature extraction to diagnose cardiac diseases (Gia et al. 2015)	IoT	This infrastructure is characterized by facilitating autonomous data capture, event transfer, data analytics, information presentation, and interoperability (see Figure 1). Devices (things) are considered smart, can be physical or virtual, have a pervasive presence, and harvest information from the environment (see Figure 8). The infrastructure uses cloud computing as a unified framework for sharing information (see Figure 1).	-

			Devices use unique addressing schemes based on MAC tracking (see Figure 8).	
3	System composed by a set of multiple inverted pendulums controlled by one processor (Zhang et al., 2008).	CPS	Typical control system that is autonomous (see Figure 4). Carries out monitoring and control over physical processes that occur in the system itself (see Figure 11).	-
4	Semiautonomous intelligent wheelchair with a BCI-based control (Schirner et al., 2013)	HiTL CPS	Semiautonomous control system, with a human in the control loop, designed to minimize the troublesome human factors (see Figure 5). It includes different kind of robotic devices, agents and embedded systems (see Figure 12).	-
5	Artificial leg with a neural-based control (Huang et al. 2010) equipped with an embedded microcontroller and a graphic processing unit (GPU) among other components	CPS	The control system is not autonomous (Figure 11) since a human is involved in the control loop. It includes an interface to the human involved (see Figure 5).	HiTL CPS
6	Set of defense systems such as aircraft, spacecraft, naval vessels, ground vehicles, etc. (Liu et al. 2017)	CPS	Some of the systems are not totally autonomous (see Figure 11) since a human is involved in the control loop. The semiautonomous systems include also an interface to the human involved (see Figure 5).	HiTL CPS

7	System to augment a commercial road capable to react to people physical malaise, malicious intrusions, and fire event detection within the commercial activities (CAs) (Cicirelli et al. 2018)	SIoT (one of the components)	Evolution of IoT (see Figure 2). Distributed service platform that integrates IoT and a social network (see Figure 2). It eases the exploitation of things-related services (see Figure 2). It has the ability to define and manage social relationships between resources (see Figure 2) based on proximity, for example. The service platform improves the discovery of services, resources, and information and the composition of services (see Figure 2). Objects can crawl the IoT through social relationships (among objects). They carry out the discovery of services, resources, and information, and the composition of services (see Figure 2).	-
8	Retail system that offers using users' smartphones notifications and recommendations about malls based on their location and interests to improve their shopping experience, as well as optimizes the mall warehouse, and gives feedback to manufacturers (Archana et al. 2019)	IoP	The system/platform supports the deployment of services/applications through which people and things/devices interact (see Figure 3). Personal devices act as humans' proxies in the cyber-world (and also as interfaces to people) (see Figure 9). The system stores and uses users' behavior and preferences (up to a certain extent) embedded into the system algorithms (see Figure 3). It is human centric and a specialization of IoT (see Figure 3). Things and personal devices instrument the environment (see Figure 9). The system allows the sharing and exploitation of human's resources, mainly information about products preferences (see Figure 3). It is data and knowledge management centric (see Figure 3). The environment has an information need (see Figure 9).	-

9	Smart transportation system that manages the automatic and anonymously reporting from people's smartphones. Smartphones can connect and communicate with others nearby to share information regarding issues affecting to their owners as well as send information to city's transportation control systems regarding where users live and work, the routes they usually take and when. This control system uses the information for simulations and previsions of potential traffic problems and to plan improvements in the city sending traffic alerts and information about new or alternative routes to smartphones (Miranda Carpintero et al., 2015)	IoP	The system/platform supports the deployment of services/applications through which people and things/devices interact (see Figure 3). Personal devices act as humans' proxies in the cyber-world (and also as interfaces to people) (see Figure 9). The system learns, stores and uses users' behavior and information (up to a certain extent) embedded into the system algorithms (see Figure 3). It is human centric and a specialization of IoT (see Figure 3). Personal devices (and things) instrument the environment (see Figure 9). The system allows the sharing and exploitation of human's resources, mainly information about routes (see Figure 3). It is data and knowledge management centric (see Figure 3). The environment has an information need (see Figure 9).	-
10	Distributed system that detects different emergency or illness situations that may affect users based on physiological information gathered by sensors (Macías et al. 2019)	IoT IoP	The system is clearly people-centric, exploits the Internet to connect people and different devices and sensors, and serves as a platform for the deployment of services that support people and things interaction among other aspects (see Figure 3). Personal devices act as humans' proxies in the cyber-world created by the system and also as an interface (see Figure 9). The system uses cloud computing as a unified framework for sharing information (see Figure 1).	-
11	Self-organization of the resources (three types of interacting robots) of a Cyber-Physical-Social system (CPSS) based on information from operation (user preferences, information from operational level services and from other robots about the results of their actions, etc.) that solves the task of pick-and-place an object from production to warehouse (Smirnov et al. 2015)	CPSS	Complex system made up by a cyber system, a physical system, and a social system. It is the enabling technology for the integration of computers, things and humans (see Figure 7). This complex system is an extension of social networks (see Figure 7). The complex system is a kind of CPS and, according to the description, uses human and social dynamics from social networks as an integral part to optimize the operation control, which should be effective, and the operation management of the system (see Figure 7).	-

			The complex system carries out self-synchronization and parallel execution as part of the (system) operation, which should be safe, reliable, and efficient (see Figure 7).	