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Intelligent Services in the IoE Paradigm: A New Age of Collaboration

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Abstract. Internet-based paradigms and technologies supported by the Internet of Everything (IoE) gain notoriety by integrating people, sensors, data, and processes in the most diverse applications, especially in collaborative approaches. Intelligent services utilize technologies like Artificial Intelligence (AI) to facilitate teamwork and joint efforts in various environments. Despite its vast potential, a significant knowledge gap exists regarding collaborative approaches for intelligent services within the IoE paradigm. This work conducts a Rapid Review to elucidate contemporary methodologies for intelligent services within IoE and explores forthcoming collaboration trends. We use the 3C Collaboration model to categorize the selected literature based on Communication, Coordination, or Cooperation approaches. Findings highlight a predominant focus on Education, particularly emphasizing paradigms like Intelligence in Learning Things. Smart Cities and Industry 4.0 are also given attention, integrating elements from the Social Internet of Things and Sustainable Collaborative Networks. Future collaboration trends indicate the rise of the Social Internet of Things, which utilizes social network strengths to overcome IoT limitations, fostering collaboration and improving operational efficiency and scalability within distributed networks. This research contributes to a thorough comprehension of current collaborative methodologies within the IoE paradigm, along with insights into future collaboration trends.

1. Introduction

The Internet of Everything (IoE) expands upon the concept of the Internet of Things (IoT) by incorporating the human component into the IoT network (Costa 2022). IoE is the global network through which people, things, and intelligent devices are connected and share information and services (Raj and Prakash 2018). IoE is a much broader concept than IoT, expanding to people, processes, and data in addition to things, making network connections more relevant and valuable, with great potential to be exploited for value extraction (Miraz et al. 2018). IoE aims to enhance the quality of life by facilitating innovative interactions among humans, processes, data, and objects (Nezami and Zamanifar 2019). IoE provides more than machine-to-machine interactions, including connections from person-to-machine and person-to-person (Bodduna 2019). The IoE paradigm can gather and interpret real-time data from diverse and mixed environments, ranging from basic sensors and actuators to intricate robotic systems and from self-operating service agents to human participants (Yu et al. 2018).

Integrating Artificial Intelligence into smart devices facilitates the growing rollout of innovative and practical IoE-centric applications. These applications allow meaningful interactions between people and objects within a social framework and multi-user settings (Miraz et al. 2018).

The growth of smart devices to support IoE applications provides new ways to benefit from human-machine collaboration. In this context, collaboration is the synthesis of communication, coordination, and cooperation – an idea originally encapsulated in the 3C Collaboration model by Ellis et al. (1991). In the 3C Collaboration model, *Communication* involves sharing messages and information between individuals; *Coordination* is related to managing people, their activities, and resources; and *Cooperation* is concerned with productive actions occurring within a shared space (Fuks et al. 2005).

In IoE, a notable knowledge gap exists regarding current collaborative approaches for intelligent services that facilitate communication, coordination, and collaboration. Our research addresses this gap through two primary inquiries: current strategies within IoE and future collaborative trends regarding IoE. This work provides a Rapid Review of IoE and Collaboration and a classification using the 3C Collaboration model.

We expect this work to advance our understanding of current collaborative approaches for intelligent services that support communication, coordination, and collaboration in the IoE paradigm and future trends in collaboration regarding IoE. In addition, it categorizes the references using the 3C Model as a framework.

The remaining text is organized as follows: in section 2, we provide the theoretical background for IoT, IoE, and Intelligent Services. In section 3, we present the methodology used in this work. In section 4, we present and discuss our findings. In section 5, we provide our final remarks.

2. Theoretical Background

This section presents the theoretical background to understand concepts such as the Internet of Everything and Intelligent Services while presenting a few related works.

2.1. From the Internet of Things to the Internet of Everything

The Internet of Things involves connecting various devices through the Internet. This vast network comprises devices equipped with built-in sensors linked to an IoT platform, facilitating the collection and exchange of information through machine-to-machine communication (Bodduna 2019).

The Internet of Everything, shown in Figure 1, revolves around four core pillars: People, Data, Processes, and Things. Information sharing and collection occur through various modes, such as Machine-to-Machine (M2M), Person-to-Person (P2P), or Person-to-Machine (P2M) communication (Wu et al. 2019). In that sense, Bellini et al. (2021) argue that the IoE can be seen as a logical evolution of the IoT paradigm, distinguished by four essential components:

- People: Individuals serve as sensors and sources of knowledge, aiding in data collection, decision-making, behavior modification, and more (Bellini et al. 2021).
- Things: Intelligent devices or machinery equipped with physical sensors and actuators responsible for generating and processing a significant volume of data (Bellini et al. 2021).
- Data: The unprocessed information created, shared, analyzed, and utilized to make informed decisions and implement effective control strategies, enhancing knowledge processes (Bellini et al. 2021).
- Processes: Strategic and value-enhancing interactions designed to deliver pertinent information to the appropriate recipient at the optimal time through the most effective channels (Shilpa et al. 2019).

Kanade (2022) compared the Internet of Things and the Internet of Everything using definition, goal, communication, and hierarchy characteristics. The comparison is presented in Table I. The Internet of Everything extends upon the foundational elements of the Internet of Things, incorporating intelligent network systems (Raj and Prakash 2018). As an advanced version of the Internet of Things, the Internet of Everything is not limited to physical devices but extends to people, things, data, and processes. According to Kanade (2022), the Internet of Everything market reached $1,074.1 billion in 2022 and is forecasted to surge to $3,335.1 billion by 2030.

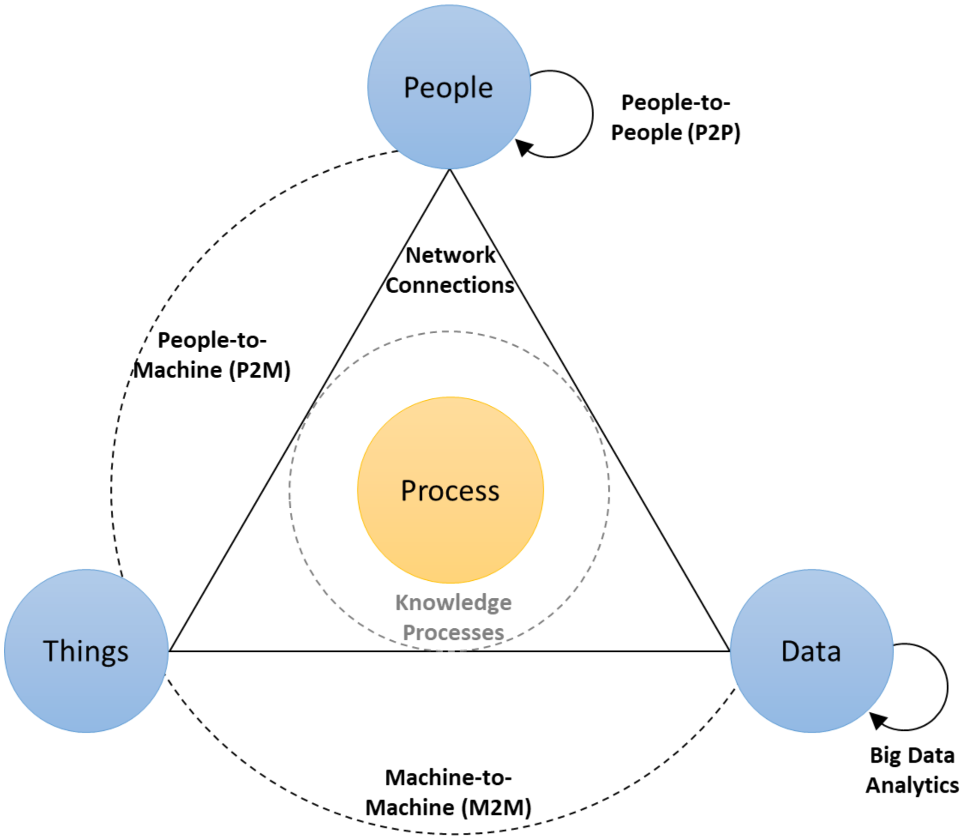

Figure 1. Internet of Everything elements, adapted from Miraz et al. (2015) and Kanade (2022).

Table I. Comparison between IoT and IoE, adapted from Kanade (2022).

Characteristics	**Internet of Things (IoT)**	**Internet of Everything (IoE)**
Definition	IoT is about physical devices that communicate without human intervention.	IoE is the intelligent network connection between four elements: people, things, data, and processes.
Goal	IoT aims to develop an ecosystem where physical objects are connected.	IoE has four primary goals: collect data and convert that data into actions, facilitate data-based decisions, enhance the capabilities of participating units, and provide advanced networking opportunities.
Communication	IoT supports machine-to-machine (M2M) communication.	IoE facilitates machine-to-machine (M2M), people-to-machine (P2M), and people-to-people (P2P using tech) communication.
Hierarchy	IoT is a subset or a part of IoE.	IoE is a superset that gives IoT a bigger picture.
Examples	Home surveillance systems, autonomous irrigation systems, connected home appliances, and smart energy grids.	Smart city environments, smart supply chains, and fitness bands that use heartbeats to pay health insurance premiums.

2.2. Smart and Intelligent Services

Advancements in communication technology have driven the proliferation of IoT devices. These interconnected devices collect, process, and communicate data in real-time, enabling modern intelligent services (Zhou et al. 2023). The terminology Smart Services and Intelligent Services is used. However, they present subtle differences in meaning.

Smart Services use technologies such as sensors, IoT devices, and automation to enhance the functionality or efficiency of a service. Smart services typically involve actuation, coordination, communication, and control, supported by virtual or physical resources (Fischer et al. 2020).

Intelligent Services implies a higher degree of sophistication than Smart Services. Koldewey et al. (2020) describe Intelligent Services as data-based services connected to intelligent objects that allow continuous and interactive feedback. Cummaudo et al. (2019) noted that creating intelligent services diverges from conventional services because it incorporates components grounded in Artificial Intelligence. These intelligent services focus their predictions on training datasets, presenting outcomes as likelihoods matching labels (Cummaudo et al. 2019). In addition, Marquardt (2017) defined an intelligent service as part of an intelligent task performed by a computer system, with behavior equivalent to that of a human being when performing a similar task.

2.3. Intelligent Services and the Internet of Everything

Intelligent Services incorporate advanced technologies such as Artificial Intelligence, machine learning, automation, and data analytics to streamline processes (Cummaudo et al. 2019). Meanwhile, the Internet of Everything extends beyond traditional IoT devices by integrating the interconnection of people, data, and processes (Bellini et al. 2021). In IoE, people serve as sensors and sources of knowledge, with data from smart devices and individuals shared and analyzed to facilitate informed decision-making.

Therefore, the relationship between Intelligent Services and the Internet of Everything lies in the interconnection between devices and people and the use of advanced technologies to improve services and processes. While Intelligent Services leverage data and automation to provide valuable information (Yang et al. 2009), the Internet of Everything integrates connections among people, data, and processes alongside traditional IoT devices. This interconnection allows data from smart devices and individuals to be shared and analyzed, contributing to more efficient and personalized services. Intelligent Services within the Internet of Everything ecosystem gather data from connected devices to improve quality of life through informed decision-making (Meridou et al. 2017).

2.4. Related work

This section aims to provide an overview of related articles focusing on Collaborative approaches for Smart and Intelligent Services. According to Stamer et al. (2020), the relationship between Collaboration and Smart Services lies in the potential of smart services to facilitate collaboration. While collaboration is recognized as advantageous for improving production processes in Global Production Networks, smart services offer an innovative approach to overcoming collaboration barriers. Smart services bridge the physical and digital worlds and boost value creation efficiency, fostering collaboration in global networks by aligning business models with customer needs.

Hu et al. (2010) explore collaboration within product development or manufacturing, involving different stakeholders, like designers, engineers, suppliers, and manufacturers, pooling resources and innovating. The nexus between collaboration and smart services is technology’s ability to augment and streamline stakeholder collaborative efforts. According to the authors, organizations can facilitate communication, improve decision-making, optimize workflows, and enable personalization by incorporating smart services into collaborative processes.

Devadasan et al. (2013) argue that collaboration and intelligent services are closely related, particularly in knowledge-based service planning. Collaborative Intelligence plays a crucial role in enhancing collaboration among service providers, ensuring the delivery of intelligent services. Some key points illustrating the relationship between collaboration and intelligent service include enhanced decision-making, efficiency and effectiveness, optimal provider selection, and tailored collaboration efforts.

Our review differs from the existing work as it centers on collaborative strategies for Intelligent Services within the Internet of Everything framework. Additionally, it delves into future trends, utilizing the 3C Model to classify the literature found.

3. Methodology

In this work, we used Rapid Review following the methodological guidelines for conducting literature reviews suggested by Hamel et al. (2021). Rapid Review is a systematic literature review approach that uses methods to streamline the review process. Rapid Reviews are lightweight secondary studies focused on delivering evidence to practitioners promptly and should be conducted according to a practical problem inserted into a practical context (Cartaxo et al. 2020). This work aims to evaluate scientific publications related to topics such as communication, coordination, and collaboration in the IoE paradigm and future trends in collaboration regarding IoE.

In this research, we searched the ACM Digital Library, IEEE Digital Library, ISI Web of Science, ScienceDirect, and Scopus. The search string used in Scopus, for example, is shown in Table II. We designed the search string to retrieve as many relevant studies as possible, narrowing current collaborative approaches for intelligent services that support communication, coordination, and collaboration in the IoE paradigm.

Table II. Search String used in Scopus.

TITLE((“CSCW” OR “Collaboration” OR “Collaborative” OR “Coordination”) AND (“Internet of Everything” OR “IoE”)) AND PUBYEAR > 2016 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE, “ar”) OR LIMIT-TO (DOCTYPE, “cp”)) AND (LIMIT-TO (LANGUAGE, “English”))

The research aimed to answer two research questions:

RQ1: *What are the current collaborative approaches for intelligent services that support communication, coordination, and collaboration in the IoE paradigm?*

RQ2: *What are the future trends in Collaboration regarding IoE?*

The research was limited to publications available since 2017. Initially, we found 157 articles. After eliminating duplicates, inaccessible, and unavailable articles, we selected 72 articles for further reading. After thoroughly reading the articles, this work critically assessed the quality of the contributions considering parameters such as the degree of adherence to IoE applications and the contribution’s relevance to human-machine collaboration in the disruptive context. Finally, after applying the analysis, only 22 relevant articles (see Table III) were able to answer satisfactorily the research questions, presenting collaborative approaches in the IoE paradigm and future trends in collaboration. The 22 selected studies were diverse and promoted different approaches to support Communication, Coordination, and Collaboration within the IoE paradigm.

4. Results

In this section, we present the results of this rapid review. First, we classify the selected articles using the 3C Collaboration Model. Next, we present collaborative approaches relevant areas in our findings: *Education*, *Smart Cities and Industry 4.0*, *Cloud-Edge Collaboration, Cyber Security, and Others*. Finally, we present findings about the future trends in collaboration regarding IoE.

4.1. 3C Model Classification

The 3C Collaboration Model is based on the idea that to collaborate, group members communicate, coordinate, and cooperate. This model originated from Ellis et al. (1991) and categorizes computational support for collaboration.

According to Gerosa et al. (2006), the definitions proposed in the 3C Model, Communication involves exchanging messages and negotiating commitments. Coordination enables managing people, activities, and resources to resolve conflicts and facilitate communication and cooperation (Gerosa et al. 2006). Finally, Cooperation involves group members working together in a shared space to perform tasks, creating and handling collaborative objects (Ellis et al. 1991).

We employ the 3C Collaboration Model to categorize the chosen articles into Communication, Coordination, and Cooperation. In Table III, the selected studies have been categorized based on the context of their application, according to the 3C Collaboration Model and the area in which their technologies belong.

With its various contributions, the field of Education had the most selected articles: 9 of the 22 articles pertained to some area of Education, such as Experiential Learning, Collaborative Learning, Special Educational Needs, Foreign Language, Learning Platforms, Knowledge Collaboration, Group Collaboration, and Note-Making Application.

4.2. Collaborative Approaches in Education

O'Connor et al. (2021) focus on managing virtual teams in large classes, addressing challenges in organizing experimental exercises in virtual environments. They discuss issues like coordinating class and team communication, building trust, and enhancing student engagement. *Coordination* is central to their analysis, especially the difficulties of coordinating large numbers of students across different countries using Virtual Teams, contrasting with traditional face-to-face classrooms. This study gains significance as virtual learning becomes more prevalent, with some classes possibly never returning to physical settings. Understanding how to maintain student engagement in this context offers valuable insights for future learning experiences.

Alkhalil et al. (2021) investigated the Jigsaw cooperative learning method to enhance students' understanding of various topics through online group learning. The case study revealed that participants in Jigsaw groups achieved a slightly higher average than conventional groups. This E-learning approach promotes self-directed learning, teamwork, and collaboration (Alkhalil et al. 2021), with *Collaboration* being particularly notable among the 3Cs, followed by *Coordination*.

Table III. Collaborative approaches based on the 3C Collaboration Model in the IoE paradigm.

Article	Context	3C Model			Area
		Collaboration	Coordination	Communication	
(Pliatsios et al. 2023)	Smart Cities	✓			Social Internet of Things paradigm
(Wang et al. 2023)	Cloud-Edge Collaboration	✓			Cyber-Physical Machine Tool
(Agrawal et al. 2023)	Supply Chain	✓		✓	Blockchain
(Dang et al. 2022)	Cloud-Edge Collaboration	✓			Social Internet of Things paradigm
(Kim and Jeong 2022)	Smart Manufacturing	✓			Virtual Reality /Augmented Reality
(Zhao et al. 2022)	Satellite Internet	✓			6G Networks
(Zhang et al. 2022)	Privacy Protection	✓			Collaborative Edge Computing
(Dong et al. 2022)	Device-to-Device Communications	✓	✓	✓	Collaborative Edge Computing, Social Internet of Things
(Gao et al. 2022)	Smart Manufacturing	✓			Dataspace
(García-Pereira et al. 2021)	Asynchronous Collaboration	✓		✓	Augmented Reality -CSCW
(O'Connor et al. 2021)	Education (Experiential Learning)		✓	✓	Virtual Teams
(Costa et al. 2021)	IoE Database	✓			Social Collaborative Internet of Things
(Alkhalil et al. 2021)	Education (Collaborative Learning)	✓	✓	✓	E-learning
(Yahia et al. 2021)	Smart Cities (Smart Governance)	✓	✓		Sustainable Collaborative Networks
(Hafidh et al. 2020)	Education (Special Educational Needs)	✓	✓	✓	Smart School Care Coordination System
(Sanchez et al. 2020)	Industry 4.0, Smart Manufacturing	✓	✓	✓	Artificial Intelligence, Data Mining, Everything Mining
(Queralta et al. 2019)	Autonomous Vehicles	✓	✓	✓	IoE Architecture
(Satu et al. 2018)	Education (Learning Platform)	✓		✓	Intelligence of Learning Things
(Magnussen and Stensgaard 2019)	Education (Knowledge Collaboration)	✓			Citizen Science, IoT, Big Data
(Happa et al. 2019)	Cyber Security	✓		✓	Collaborative Mixed-Reality
(Deng et al. 2018)	Education (Group Collaboration)	✓			Web 2.0, Wikispaces
(Towey et al. 2017)	Education (Note-Making Application)	✓			Open Educational Resources

Hafidh et al. (2020) present the School Care Coordination System, a knowledge-based platform built on a six-layered data management model. It integrates education, health, and social care services, translating special educational needs and disabilities guidelines into a comprehensive knowledge system. The School Care Coordination System aims to streamline coordination and monitoring, providing personalized care plans for children and young people with disabilities by unifying education, health, and social care into one application.

Satu et al. (2018) present the Intelligence of Learning Things educational platform, integrating IoT with traditional education for innovative learning strategies. Intelligence of Learning Things facilitates collaboration among devices and applications, fostering a more innovative educational environment for stakeholders, including teachers and students. In this study, *Collaboration* stands out as the primary aspect of the 3C Model, followed by *Communication,* encompassing both people-to-people and people–to-machine communication, which are characteristics of the Internet of Everything outlined in Figure 1.

Magnussen et al. (2019) reviewed collaboration trends in citizen science, crowdsourcing, and community-driven research from 2013 to 2018. The study highlights man-machine collaboration, with Human-Machine Information Systems as the dominant sub-theme, enabling efficient data processing through human contributions and machine learning.

Deng et al. (2018) explore the use of wikis and other Web 2.0 tools by first-year teacher education students at a university for group work purposes. The findings indicate a deviation from the instructor's original plan to use wikis as the central collaborative space. Instead, students employed various technologies during group work, including Facebook for communication, Diigo for saving, sharing, and annotating, and Google Drive for pooling drafts and notes. This study illustrates practical preferences in organizing *Collaboration* efforts.

Finally, an interdisciplinary team of teachers and computer science students collaborates to create an Open Educational Resource that is freely available for educational use and supports students' note-taking and research (Towey et al. 2017).

The Education topics covered in the field exhibit diversity. While all touch upon Collaboration, four include Communication, and only two address Coordination. Results show that Collaborative approaches within the IoE span from digitizing tasks previously confined to the physical realm. Examples include older paradigns such as Virtual Teams, E-learning, Web 2.0, and Wikispaces, as well as newer paradigms like Smart School Care Coordination Systems, Big Data, Intelligence of Learning Things, Citizen Science, and Open Educational Resources. This extensive range indicates the unexplored terrain in education concerning collaborative approaches for intelligent services that support communication, coordination, and collaboration within the IoE paradigm.

4.3. Collaborative Approaches in Smart Cities and Industry 4.0

Alavi et al. (2018) described a *Smart City* as a contemporary urban environment that operates intelligently and sustainably to guarantee sustainability and efficiency. This description entails the integration of diverse infrastructures and services, all overseen and managed by intelligent devices.

With that in mind, Pliatsios et al. (2023), Kim and Jeong (2022), Gao et al. (2022), Yahia et al. (2021), Sanchez et al. (2020), and Queralta et al. (2019) broadly discuss Smart Cities. Specifically, Kim and Jeong (2022), Gao et al. (2022), and Sanchez et al. (2020) focus on Smart Manufacturing — methods that can use IoT technologies and web-based services to communicate and interact with other products in a factory environment (Kim and Jeong 2022). The first two studies explore the *Collaboration* aspect of the 3C Model, while the latter encompasses all 3Cs.

Sanchez et al. (2020) explore Industry 4.0’s integration challenges, emphasizing the importance of innovative solutions to ensure interoperability and self-organization. They argue that 3C processes empower humans and robots to perform intelligent tasks, addressing critical issues like integration and interoperability within production processes. In this context, *Coordination* is the synchronization of activities, resources and actors to achieve common goals efficiently, and plays a crucial role in manufacturing. In the context of Industry 4.0, coordination is essential for seamless communication and collaboration among various smart factory components, facilitated by advanced technologies like AI and data analytics to optimize production processes and enhance overall productivity.

Yahia et al. (2021) focus on Smart Governance, highlighting the importance of cultivating collaboration within the government for effective smart city governance. They emphasize adaptive policy-making to foster internal and external collaborations. Queralta et al. (2019) explore Autonomous Vehicles, introducing an IoE-based architecture integrating cars and drones. Their mixed-team approach enhances situational awareness in autonomous vehicles, showcasing the potential of IoE in the transportation sector.

Within the Smart Cities framework and its subdivisions, various areas, including Social Internet of Things, Virtual Reality, Augmented Reality, Dataspace, Sustainable Collaborative Networks, Artificial Intelligence, Data Mining, and Everything Mining, constitute the collaborative approaches for Intelligent Services supporting Communication, Coordination, and Collaboration in the IoE paradigm.

4.4. Collaborative Approaches in Cloud-Edge Collaboration, Cyber Security and Others

Cloud-edge collaboration is analyzed by Wang et al. (2023) and Dang et al. (2022). Wang et al. (2023) introduce a cloud-edge collaborative architecture for Cyber-Physical Machine Tools addressing resource underutilization and cloud pressure. Dang et al. (2022) propose a road damage classification method based on edge computing, enhancing response time with an edge server between the user and the cloud. Dong et al. (2022) present the recent advanced applications and developments in collaborative edge computing for the Social Internet of Things (SIoT). The *Communication* of the 3C Model is emphasized in machine-to-machine communication, characteristic of the Internet of Everything in Figure 1, emphasizing the importance of communication speed.

On the other hand, Zhang et al. (2022) and Happa et al. (2019) were concerned about Privacy Protection and Cyber Security, respectively. Zhang et al. (2022) introduce data protection for Collaborative Edge Computing in social IoT systems to prevent privacy breaches. Likewise, Happa et al. (2019) investigate cyber-security threats to Collaborative Mixed-Reality systems, focusing on network vulnerabilities. Based on the 3C Model definition of *Collaboration*, their work explores how Collaborative Mixed-Reality integrates Mixed-Reality technologies with collaborative interfaces, enabling real-time interaction in shared virtual environments. These applications facilitate teamwork and productivity by allowing users to collaborate on tasks, projects, or activities in a shared virtual space, emphasizing the importance of secure and private collaboration.

Other topics mentioned in the literature include Supply Chain using Blockchain (Agrawal et al. 2023), Satellite Internet with 6G (Zhao et al. 2022), Asynchronous Collaboration with Augmented Reality-CSCW (García-Pereira et al. 2021), an IoE Database for collaboratively cataloging IoE applications (Costa et al. 2021), and the introduction of the Social Collaborative Internet of Things paradigm (Khan et al. 2017) – in which social objects interact and share information to achieve a common goal.

Regarding collaborative approaches in Cloud-Edge collaboration, the literature explored Cloud-edge collaboration for Cyber-Physical Machine Tools, road damage classification, and advanced applications in collaborative edge computing for the Social Internet of Things. In Cyber Security, the literature mentioned data protection for Collaborative Edge Computing in social IoT systems and cyber-security threats to Collaborative Mixed-Reality systems.

4.5. Future trends in Collaboration regarding IoE

While the Internet of Things offers increased connectivity, its traditional networks often fall short in intelligence, context awareness, and interoperability, limiting their potential to add value for businesses and individuals (Noura et al. 2019). This gap is addressed by the Social Internet of Things paradigm, which merges the strengths of social networks with those of IoT to create a more collaborative and efficient system (Roopa M.S. et al. 2019).

A key advantage of SIoT is its capacity to promote collaboration and cooperation among devices and applications. This capacity leads to a more streamlined and effective operation where multiple components can work together to achieve shared objectives (Amin et al. 2022). Additionally, the exceptional scalability of the Social Internet of Things enables the management of substantial data volumes and devices, facilitating the creation of intricate distributed networks (Shahab et al. 2022). Therefore, SIoT is emerging as a focal point for future collaborative initiatives in service and data science.

Another emerging trend is the Autonomic Cycle of Data Analytics Tasks, defined by Aguilar et al. (2017). It comprises a coordinated group of data analysis tasks to fulfill a specific goal in the process they oversee (Sanchez et al. 2020). These tasks are interdependent, each playing a distinct role within the cycle. Additionally, Sanchez et al. (2020) propose an Autonomic Cycle for Coordination in Industry 4.0. It outlines a series of data analysis tasks to enable self-planning, self-supervision, and self-configuration in manufacturing. It empowers stakeholders to make informed decisions for enhancing factory efficiency, detecting failures, and system repair. As a result, a Smart Product can actively guide its production by coordinating various actors involved.

Another emerging approach leverages the existing computing resources at industrial sites to offload Digital Twin modeling and data processing from the cloud to the edge. Traditionally, devices were primarily used for production tasks and real-time data collection, with data processing centralized in the cloud. However, as the Internet of Everything expands and intelligent algorithms evolve, the massive volume of data and computational demands in industrial settings has skyrocketed (Wang et al. 2023). Relying solely on cloud computing can result in significant delays and data isolation, failing to meet real-time data interaction requirements (Liu et al. 2019). For this reason, the transition to edge computing is increasingly gaining attention.

5. Conclusion

The Internet of Everything integrates people, sensors, data, and processes in the most diverse applications. However, there is a significant gap regarding collaborative approaches for intelligent services in the context of the IoE. In this work, we performed a Rapid Review to improve the comprehension of contemporary methods for such services in the IoE paradigm and explore future collaboration trends. The selected articles are analyzed using the 3C Model to categorize their collaborative approaches into Communication, Coordination, or Cooperation.

Findings reveal a predominance of literature on Education, particularly emphasizing paradigms such as Intelligence of Learning Things. Subsequently, attention is directed toward Smart Cities and Industry 4.0, featuring elements from the Social Internet of Things and Sustainable Collaborative Networks. The Cloud-Edge and Security domains also showcase technologies like Cyber-Physical Machine Tools and Collaborative Mixed-Reality, among other subjects. The results of this work also indicate that future trends in collaboration include the rise of the Social Internet of Things, addressing IoT limitations by merging social network strengths for efficient operations. SIoT fosters collaboration while streamlining processes and exhibits exceptional scalability for intricate distributed networks. Additionally, emerging trends involve Autonomous Cycles for Data Analytics Tasks and the shift to Edge Computing from the cloud in response to the expansion of the Internet of Everything.

The main contributions of this work include a broader understanding of current collaborative approaches for intelligent services in the IoE paradigm while providing future collaboration trends. This work also contributes to the literature when categorizing selected articles using the 3C Collaboration model as a framework.

This work also leaves some avenues for research, including a deeper understanding of collaboration in the Social Internet of Things and Collaborative Mixed Reality. Although Smart Cities and Industry 4.0 are well-researched subjects, we recommend further research in Sustainable Collaborative Networks.

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