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PERSPECTIVE

Internet of Things to Internet of Humans: A Perception

Ghazanfar Ali Safdar[1] · **Mohammed Bahja**[2] · **Mujahid Muhammad**[3]

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Abstract
The use of internet has grown significantly in the last three decades. Various technologies such as social media and networking, cloud systems, Blockchain technology etc., have been developed which have significantly improved the communication between the humans across the globe; and also, between the devices which has led to the development of approaches like the internet of things (IoT). These approaches have been increasingly adopted in various sectors including healthcare, education, retail, financial, and many other sectors. However, the development of the internet and its relevant technologies were mainly focusing on the technical aspects undermining the human-centric aspects which has led to the development of new concept called 'Internet of Humans (IoH)'. There is a lack of research and understanding relating to the internet of humans, and no clear definition was identified. In this context, this paper tries to explore the concept of the Internet of Humans from different perspectives including advanced and innovative supporting technologies, human-centric factors, and areas of application. Thus, this paper contributes to the development of literature for understanding the internet of humans and proposes future research issues and challenges.

Keywords Internet of humans · Internet of Things · Human centric factors · IoT to IoH

Abbreviations

IoT	Internet of Things
IoH	Internet of humans
IoE	Internet of everything
AoE	Automation of everything
HCI	Human computer interaction
ML	Machine learning
AI	Artificial intelligence
DL	Deep learning
NLP	Natural language processing
DTs	Digital twins
GDPR	General data protection regulation

1 Introduction

The world that we live in today is completely different from the world that existed three decades ago, i.e., before the release of the internet to the general public by European council for nuclear research (CERN). The internet has almost impacted every aspect of human lives. There has been an unprecedented expansion in terms of its use and the range of available services using the internet in the last thirty years. The number of global social media users have grown from 2.73 billion in 2017 to 5.17 billion to date, almost 3 times increase in period of 6 years, it is expected that the users' number will grow to 5.85 billion by 2027, [1, 2]. The number of global internet users have grown from 1.023 billion in 2005 to 5.40 billion in 2023, almost five times increase in just 18 years, [3], Fig. 1. These statistics reflects the globally connected world through real-time communication systems, which once were thought to be impossible.

Exponential growth of the internet has made it a major social, economic, technological, and political driver, and it would be complex to estimate the size of internet market as its contributions need to be assessed from various perspectives including values, growth, empowerment etc. The internet enabled the digital transformation of various sectors of economy leading to the development of innovative

✉ Ghazanfar Ali Safdar
ghazanfar.safdar@beds.ac.uk

[1] University of Bedfordshire, Luton LU1 3JU, UK

[2] University of Birmingham, Birmingham B15 2TT, UK

[3] Birmingham City University, Birmingham B4 7XG, UK

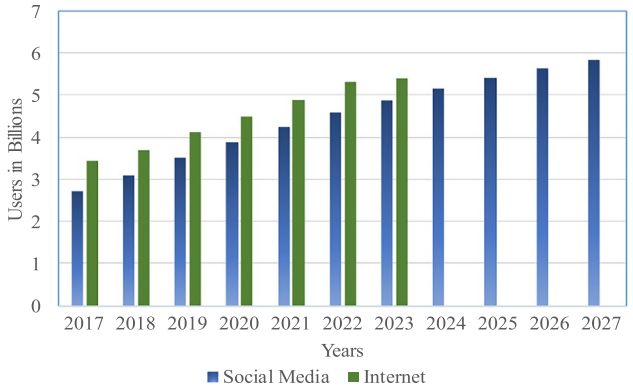

Fig. 1 Social media and internet users [1, 3]

business models which are effective and efficient in managing operations and delivering services that are replacing traditional models in various sectors. However, the most important factor that humans need to consider is that how the internet has transformed our society: the ways of living, working, interactions, being informed, decision-making, and ways geographical borders are disappearing in exchanging services in the digital world due to reliance on the internet. The growing importance of the internet in the recent years reflects that the internet is no more a communication technology or networks, since it has rapidly influenced the human lives in every possible context. This raises the basic questions about the use of internet for future, such as is the current internet evolving according to the changing needs of the people. What is the role of policy-making, companies and people in driving the evolution of the internet? Which areas require the innovative research; can we leave the innovations and decision-making in the hands of few regarding the regulation of the internet or should we adopt a bottom-up democratic approach in decision-making to regulate the use of internet for future.

Many people across the world still have concerns about using the internet and communication technologies. A study conducted by Atomium European institute [4] through a public campaign by collecting and analysing the public views on the impact of future internet technologies has identified various concerns which include privacy, cybersecurity and cybercrime, fear of losing jobs through automation of services, contributing to rising populism etc. While 24–38% strongly agreed that future Internet technologies could improve our society through increasing access, availability, cost-effectiveness, and personalisation of public services; 12–25% strongly disagreed, indicating a varying level of opinions among the use of internet, and related concerns about the possible impact of the internet on humans in future. The research on the use of internet for future [5–8] leading to adoption of innovative models such as Internet of Things (IoT), focusses mainly on the application of the internet on things while paying little attention to human perspectives such as their concerns, their behaviours, attitudes etc. This has led to the rise of new approach called Internet of humans (IoH). In this context, this paper explores and reviews the concept of IoH and its dimensions from various perspectives to enhance understanding about the importance of IoH as a futuristic approach.

The significance of this research study lies in its timely exploration of IoH, a concept that is critically important yet underrepresented in existing literature. While much attention has been devoted to the development of IoT, there remains a noticeable gap in addressing the human-centric dimensions of internet technologies—particularly concerning trust, inclusion, usability, and behavioural engagement. The originality of this study stems from its interdisciplinary approach, which expands the conventional definition of IoH beyond technical functionalities to include psychological, socio-economic, and ethical considerations. The key contributions of this paper include:

- A comprehensive definition and conceptual framework for IoH.
- A critical comparison between IoT, Internet of Everything (IoE), Automation of Everything (AoE), and IoH.
- Identification of enabling technologies and human-centric factors.
- Mapping of real-world application domains.
- A forward-looking research agenda addressing interoperability, trust, inclusivity, and policy in IoH adoption.

This paper thus serves as a foundational reference for researchers, practitioners, and policymakers engaged in shaping the future of human-centred internet technologies. The remainder of the paper is organized as follows: Section 2 introduces the concept of IoH, examining the limitations of IoT and the emerging need for a human-centric paradigm aligned with social good. Section 3 presents key enabling technologies that support the development and implementation of IoH. Section 4 investigates core human-centric factors associated with IoH, including trust, security and privacy, as well as inclusion and engagement. Section 5 explores potential application domains of IoH across various industries and societal contexts. Section 6 discusses the key challenges and outlines future research directions for advancing the IoH paradigm. Finally, Section 7 concludes the paper by summarizing the main findings and contributions.

2 Understanding IoH

It is essential to first understand the fundamental role of the internet and the rapid evolution of internet-based technologies in recent years to appreciate the significance and

uniqueness of IoH. Over the past three decades, the internet has significantly influenced various aspects of daily life, driving innovations such as social media platforms, cloud computing, blockchain technologies, and connected devices. These developments have reshaped global communication, human relationships, and business models. Despite these advances, a critical gap persists between the technologies developed and the actual human needs, behaviours, and interactions they seek to support.

IoT exemplifies this technology-driven development paradigm. It is commonly defined as "the network of physical objects ('things') embedded with sensors, software, and other technologies that enable connectivity and data exchange with other devices and systems over the internet" [9]. Typical IoT infrastructure comprises sensors, networks, actuators, and cloud intelligence, and it is estimated that over 22 billion connected IoT devices will be in use by 2025 [3]. For example, a conventional air conditioner thermostat that activates automatically based on predefined temperature thresholds represents a basic automated system. Once the thermostat is connected to the internet and can be managed remotely via a smartphone, it becomes a simple IoT device. More advanced IoT systems integrate multiple sensors—monitoring temperature, humidity, motion, and lighting—which enable remote, intelligent control and real-time automation through web-based or mobile platforms.

However, despite IoT's promise and technological capabilities, practical adoption frequently reveals human-centric shortcomings. Consider modern vehicles that integrate numerous IoT sensors primarily for monitoring engine performance, safety, and comfort. While these features provide initial excitement, users often neglect or abandon many functionalities shortly after purchase due to poor alignment with human behaviour, usability, or practical necessity [8]. This phenomenon underscores a fundamental limitation in traditional IoT development—the insufficient consideration of human usage patterns, preferences, and behavioural nuances.

Addressing these critical human-centric issues necessitates shifting from a device-centric "how the world currently works" model towards a human-centric "how the world should work" paradigm (Fig. 2). This shift encompasses recognizing and actively incorporating human behaviours, attitudes, trust, security, privacy, and inclusivity within the development and implementation of internet-connected technologies. Technologies such as quantified-self devices (e.g., heart rate monitors, stress indicators, and pulse checkers) should empower individuals by altering perceptions and behaviours towards proactive self-health management. However, this can only be effectively achieved if these technologies are explicitly designed around human experiences, needs, and expectations.

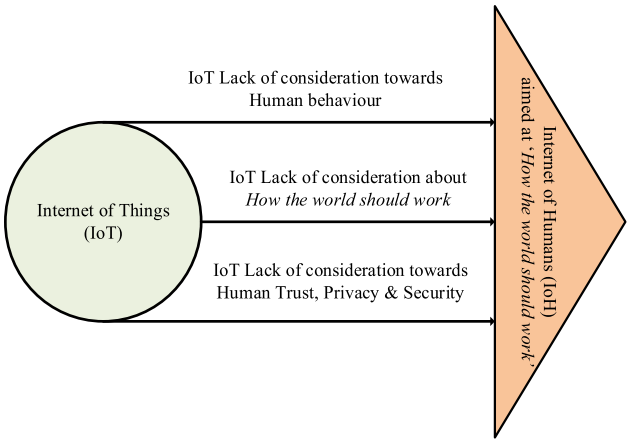

Fig. 2 IoT to IoH – how the World should work

IoH emerges explicitly from these considerations, prioritizing human-centric factors at its core. According to Roberto Viola of the European Commission, IoH is conceptualized as a next-generation internet initiative explicitly addressing essential human needs, such as trust, security, and inclusion [10, 11]. Building upon this definition, the current manuscript further expands IoH's scope by integrating behavioural analytics, socio-economic factors, ethical standards, and psychological dimensions. This expanded conceptualization positions IoH not merely as a technology but as an ecosystem explicitly designed for enhancing human experiences, responsiveness, personalization, and inclusivity.

In contrast to IoT, where interactions predominantly occur among machines and objects, IoH emphasizes direct and meaningful human engagement within interconnected environments. IoH demands interdisciplinary research and innovation involving psychology, human–computer interaction (HCI), ethics, sociology, and behavioural sciences alongside traditional technological domains. IoH-driven technologies proactively adapt and respond to human needs, enhancing trust and user experience by understanding and anticipating user behaviours, preferences, and ethical concerns.

Furthermore, to better contextualize IoH within the broader evolution of connected technologies, it is essential to define and integrate related concepts such as IoE and AoE. The IoE extends IoT's scope beyond physical objects to include people, processes, and data, thus enhancing value creation through interconnectedness across diverse sectors and domains [12, 13]. Conversely, AoE encapsulates the pervasive and systematic application of automation technologies, especially Artificial Intelligence (AI) and Machine Learning (ML), automating nearly every aspect of daily life, industry operations, and human interactions [14]. Both IoE and AoE concepts significantly complement and enrich IoH by creating environments where automation,

interconnectedness, and human-centric design seamlessly integrate, enhancing the responsiveness and relevance of digital technologies to human experiences and societal needs.

The IoH concept thus represents a comprehensive paradigm shift, moving from a purely technological and automation-driven approach toward an inclusive, ethically aware, and behaviourally responsive internet ecosystem. To the best of the authors knowledge, scholarly literature explicitly defining IoH remains limited, with most available definitions focusing narrowly on trust, security, and inclusion, as exemplified by Roberto Viola's foundational definition. This manuscript uniquely extends Viola's conceptualization by integrating comprehensive behavioural, psychological, socio-economic, and ethical dimensions, thus significantly contributing to a more holistic and interdisciplinary understanding of IoH. The following sections further explore the enabling technologies, human-centric factors, application areas, and key challenges, reinforcing IoH's potential to profoundly impact future societal and technological developments.

3 IoH Enabling Technologies

There are various innovative technologies which are increasing the prospects for future use of the internet, some of the key technologies which can support IoH are described in the following sections, Fig. 3.

3.1 Artificial Intelligence (AI) and Predictive Analytics

Innovative developments across AI are necessary to convert the rapidly increasing data into information and knowledge which are important factors for providing autonomy and intelligence into networks, connected devices, and robots [15]. In addition, predictive technologies can further enable the decision-making autonomy by training the neural networks using techniques such as ML, deep learning (DL) etc. [16]. Considering the same thermostat example as explained above, its functionalities may be increased by applying AI technologies where different factors such as moisture, humidity, power fluctuations can be sensed through AI enabled technologies to provide more customised services. Furthermore, ML technologies can enable air conditioners to observe and learn users' behavioural data with respect to AC usage and other devices connected to IoT, and accordingly streamline their performance. Focusing on a futuristic application, for example, a smart-home enabled with various health monitoring devices can track users' health-data in real-time using AI technologies, and can learn the health conditions of the residents through ML

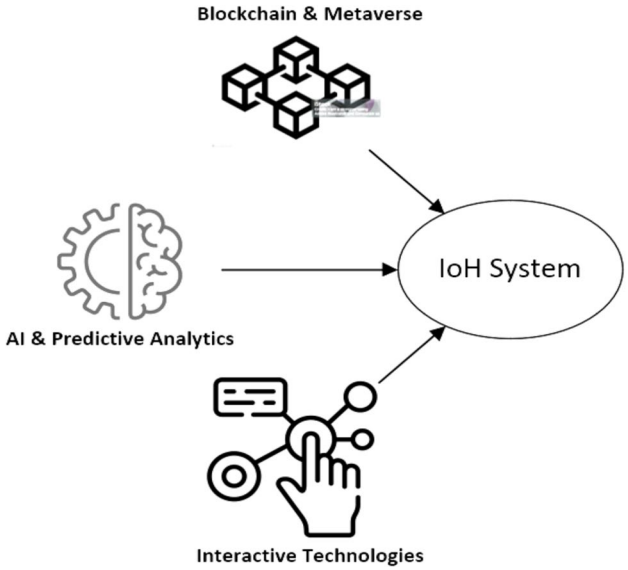

Fig. 3 IoH enabling technologies

techniques. AI and predictive technologies can learn about Human Behaviour leading towards enactment of IoH. In case of any emergency, to address the missing component of as how the world should work, IoH in smart homes can alert the nearest recognised care giver or health professional to act accordingly, timely and to serve human needs [10].

3.2 Interactive Technologies

Interactive technologies can enhance human–machine interactions and lead to effective and efficient utilization of the IoT and IoH. Technologies such as augmented reality (AR), virtual reality (VR) have been identified to be increasing human experience in using various services in different sectors [17–19]. In addition, in order to make IoH applications adopt the principles of openness, diversity, and inclusion, it is very much essential that they need to be effectively used by respective sections of society including people from diverse cultures, and sections. Natural language processing (NLP) applications in this context are effective in analysing the semantics of the texts or spoken languages enabling the usability of IoH applications among the diverse groups [20, 21]. For example, considering the same thermostat example, the ability to control the air conditioner and all other connected devices using voice commands through smartphones or with devices such as Amazon Alexa, Google Home devices can further enhance the adaptability of IoT.

In addition to IoT, two related concepts significantly contribute to the development of automated and interconnected systems: IoE and AoE. IoE extends beyond IoT by interconnecting not just physical devices but also people, processes, and data, facilitating deeper integration across

sectors [12]. The IoE paradigm emphasizes maximizing the value derived from networked connections, thus transforming societal interactions and economic models comprehensively [13]. On the other hand, AoE refers to pervasive and extensive automation enabled primarily by advancements in AI, ML, and autonomous systems, aimed at automating virtually every aspect of human interaction, work, and daily life [14]. Both IoE and AoE significantly complement the IoH concept by creating interconnected and automated environments that explicitly include human behaviours, preferences, and ethical concerns as essential considerations, reinforcing human-centric system design principles.

3.3 Blockchain and Metaverse

A Blockchain is a shared, immutable ledger which can facilitate various operations such as recording transactions, tracing assets (tangible and intangible) in a network. In any business, it is important that the information shared has to be accurate and delivered quickly in a safe and secure manner. Considering the human-centric issues such as privacy, security and reliability, blockchain technology can be an effective solution, as it provides immediate, shared, and completely transparent information stored on an immutable ledger that can be accessed only by permitted network members. Due to its enhanced operational capabilities in a secured manner, blockchain technology can be effective in managing IoH devices [22], addressing security and privacy challenges. Considering the same thermostat device in this context, a user can manage the operations of various interconnected devices in a smart home from a remote location in a secured manner. Similarly, blockchain technologies may be effective in handling safer transactions when intelligent cabs, transport companies, and customer without drivers are deployed by organizations such as Uber in future. Thus, it can be effective in handling and managing various transactions in different sectors, and accordingly to address security issues of IoH.

Complementing blockchain, the emerging Metaverse concept significantly contributes to shaping the future internet, particularly from a human-centric perspective [23]. The Metaverse can be understood as the expansion of Digital Twins (DTs)—virtual representations of real-world entities—into the broader social and human domains. Essentially, it represents a three-dimensional, immersive evolution of the traditionally linear internet, enabling realistic and interactive digital environments that deeply integrate human social interactions, commerce, education, entertainment, and governance.

Integrating blockchain within the Metaverse can offer unprecedented security and user empowerment by managing digital identities, securing digital assets, and ensuring transparent interactions in virtual environments. Such integration supports the vision of IoH by enhancing user trust, promoting inclusivity, and fostering secure, meaningful, and engaging human experiences. For example, blockchain-enabled Metaverse platforms could provide secure digital identities for virtual healthcare consultations, trusted educational credentials, secure virtual marketplaces, or immersive interactive social spaces, thus exemplifying practical IoH applications. Hence, the combined potentials of Blockchain and the Metaverse align seamlessly with IoH objectives, significantly enriching user experiences, reinforcing trust, and promoting more inclusive and interactive digital ecosystems.

4 IoH and Human Centric Factors

Human-centric factors can be understood from two perspectives. Firstly, to what extent the internet and connected devices consider human-centric factors in developing a technology; Secondly, developing the next generation internet of humans which considers factors such as trust, privacy and security, engagement and inclusion. As explained about the fact that most of the sensors used in automobiles, after a while remain unused by the drivers because human considerations were not considered in designing and developing those sensors; accordingly, the same can be considered in this context. Key human centric factors in the context of IoH are discussed below, Fig. 4.

4.1 Trust

Trust is an important driver for the internet technologies; accordingly, trust is one of the major concerns among the consumers regarding these technologies. In a survey

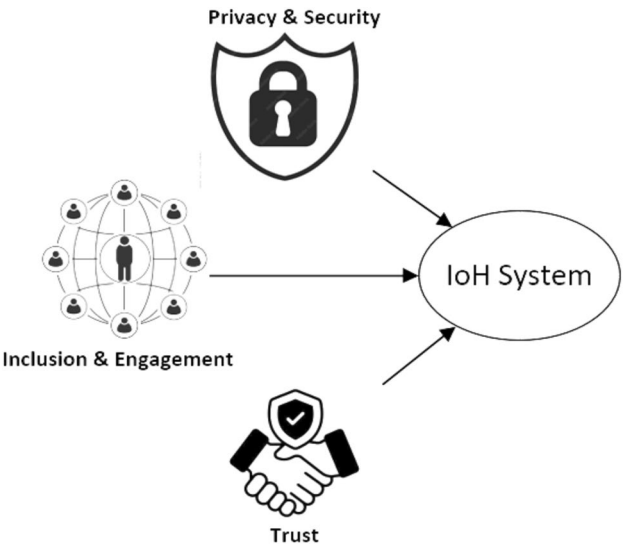

Fig. 4 IoH human-centric factors

conducted by centre for international governance and innovation in 2020 with over 25,000 internet users across the world, has revealed some interesting aspects which include: more than 75% of users stated that social media companies (Facebook, Twitter, and others) are responsible for their distrust on the internet, surpassing cybercriminals as the major factor for lack of trust. Over 53% were more concerned about their privacy than a year ago; 86% were fallen for fake news; and 49% changed the way they behave online due to lack of trust, such as not sharing complete personal information. These trends reveal the poor trust levels of the consumers on the internet. Therefore, it is important to achieve trust among all the stakeholders to further progress in the internet technologies. However, the research on trust related factors involving internet and the connected devices, states that the factors affecting trust need to be considered from a multi-dimensional aspect as they may be related to various domains such as product related factors, social influence related factors and security related Factors etc., which may affect the adoption of internet technologies such as IoT [24]. Defining the level of autonomy by the users to an extent lead to the adoption of these systems, however, the distrust may continue to exist among the consumers [25]. Thus, trust continues to be an important human-centric factor that could affect the adoption of internet technologies in the context of IoH.

4.2 Privacy & Security

The internet has undoubtedly led to the rapid globalization removing the boundaries in communications across the world. This has led to the increase in communication between the strangers, whether it is sharing personal details while booking a hotel or renting an IoT enabled smart home, affecting the privacy of the consumers [26]. However, information sharing has become an essential operation in order to facilitate transactions over the internet, without which it may not be possible for completing transactions. Nevertheless, the issue is who is in control of the personal data, and what levels of autonomy do they have in using such data, and how it may affect the consumers' privacy. For instance, with over 4 billion smartphones with various features of tracking, for example, location tagging reflects the huge volumes of data which can affect the privacy of more than 50% of the world population. While using personal data can help in improving services for the consumers [27]; at the same time, it may also be used in an unethical way which can influence socio-political decisions of the citizens, affecting them in the long term [28–30]. Though there are various laws and provisions made on regulating the use of personal data on online platforms, there are still various issues of cybercrime, affecting the privacy, were being experienced in the past few years, and privacy and security remained to be the major concerns of the consumers over the past two decades [31]. To address this issue various initiatives have been taken by the European Union, such as General Data Protection Regulation (GDPR) [32], NIS directive [33, 34] etc. However, there are still lack of effective regulations and policies in many countries across the world, which is one of the major concerns for using the internet and relevant technologies in future, especially IoH.

4.3 Inclusion and Engagement

The main objective of the internet is to facilitate services for the consumers. It is opened for the society as a whole, but not for few influential parties. Accordingly, the internet should respond to the fundamental needs of the citizens, including trust, security and inclusion, and in general reflects the values and the norms in the societies. The systems developed using the internet such as IoT may should consider the concepts of social values and promote inclusion and equality in the society, by enabling the access to all people without marginalising specially-disabled, elderly, economically disadvantaged, and rural communities [35]. For example electronic health systems where patients must complete online forms describing their illnesses before any sort of treatment plans etc. can even be discussed are proving extremely difficult processes for people with little or no literacy about usage of internet, or lack of internet access and equally lack of internet enabled devices. It is fair to conclude that these technologies have eventually filtered out the elderly, less educated or people with any sort of visual or reading related disability and thus proven seriously non inclusive, rather selective. Those with internet access tend to have higher wellbeing and richer social capital outcomes than those without access [36]. Technologies have been developing for inclusion of all sections of society that can result in greater participation and engagement of consumers in IoT systems [37, 38] which can support future growth of IoH.

5 IoH Areas of Application

Since IoH is yet to be realised, there are no defined applications which can be added in this particular section. Nonetheless, the fact that IoH evolves from IoT, some key application areas are discussed in the same context, Fig. 5. The internet technologies have become an important factor in every sector. In the context of healthcare, there are various approaches such as mHealth, eHealth, health information systems etc. being used to improve the access to healthcare services and increase operational quality and efficiency. In addition, other communication technologies such as Bluetooth enabled devices are being used in the self-management practices such as diabetes, by measuring blood glucose

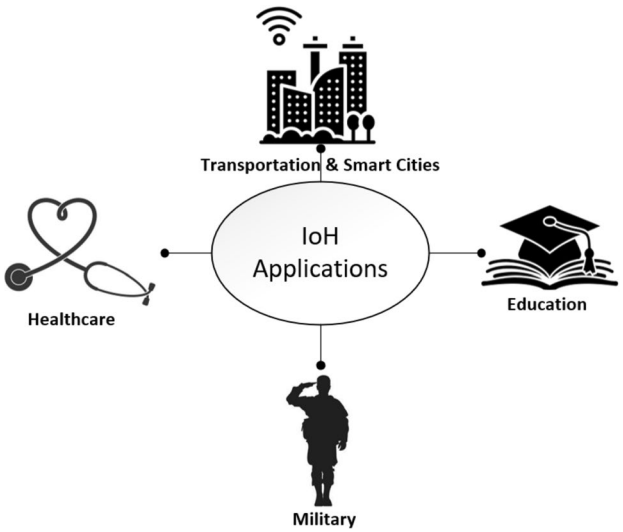

Fig. 5 IoH applications

levels through a glucometer that transmits records to the mobile application using Bluetooth technology, and the application further transmits the data to healthcare server using the internet [39]. Spire is another innovative example of IoT, which analyses the respiratory patterns and physical activities using AI technologies and provides real-time feedback and instant alerts [40]. In addition, immersive technologies have wider opportunities in healthcare and many other sectors that can improve the ways in which consumers access information and services. In addition, concept of a patient-centred medical home using the concept of IoT with various sensors and monitoring devices criteria and competencies for adoption in future has also been discussed [41]. Similarly, the paradigm of internet, humans, sensors, and communication technologies can be very much beneficial in educational sector, especially in the process of learning and experimentation [42]. For instance, a simple device such as scan marker, that can scan texts on the paper and convert them to text in the connected device application such as Microsoft Word is an effective device for making notes while reading and highlighting important points. In addition, the device has a feature that can translate the converted text into 40 languages and has an ability to read the text for the learners, indicating an effective integration of intelligence and interactive communication technologies centred around the basic human needs (learning), reflects an effective application of the internet technologies for humans.

Transportation and smart cities is another sector, where shift from IoT to IoH can have larger scope. For example, a completely automated transportation system powered by AI and ML technologies, and IoT approaches reflect the future possibilities of the internet and connected devices technology in smart cities [43]. In addition, robots are used to support the community in various services in the city and will outnumber the number of people living in the city, reflecting the impact of IoT and AI technologies on daily lives. Thus, various sectors are experiencing the revolution of the internet of things, but what is more important is that how effective are these systems in addressing the fundamental needs of the humans and this very much centres around the concept of IoH.

Military applications can also be influenced by usage of the IoH, mainly to track health, physical strength, and wellbeing of soldiers; particularly aimed to enhance physical abilities, improve training, and enable them to fight in combat situations. For instance, AR enabled headsets can be employed in battle circumstances. Military research has also invested in neuro devices to decode signals from the brain of a pilot to get control over its plane. Though these competences are possibly helpful in enhancing combat skills but poses new security risks too like brain hacking or thoughts distortion of a pilot. Lastly as the technology evolves, accordingly IoH has possibility to impact future technology related trends such as 5G use cases including, ultra-reliable low latency communication, massive machine type communication etc.

6 IoH Challenges and Future Research Directions

The IoH leverages existing IoT frameworks, integrating human-centric considerations to enhance usability, trust, and inclusivity. Despite advancements, the realisation of IoH faces several complex challenges, which demand deeper exploration and practical solutions. The following sections provide detailed insights and recommendations for addressing these challenges, highlighting potential research directions.

6.1 Interoperability and Standardization

A core challenge in IoH development is achieving seamless interoperability between existing IoT devices and new IoH frameworks [44, 45]. Devices, services, and systems developed by various manufacturers often use proprietary protocols, limiting integration and scalability. Thus, the following are some potential research directions in this context:

- Development of universal IoH communication standards and open-source frameworks to facilitate interoperability.
- Creation of middleware solutions that translate protocols across diverse IoT and IoH ecosystems.
- Conducting case studies and pilot implementations to validate and refine interoperability standards in real-world scenarios.

6.2 Privacy, Security, and Trust

Maintaining user privacy, ensuring robust security, and building trust are paramount concerns. The human-centric nature of IoH means that systems frequently interact with sensitive personal data, demanding high levels of data governance and transparency as mentioned in [31, 43]. Hence, some potential research directions include:

- Investigating privacy-preserving technologies such as federated learning, differential privacy, and secure multiparty computation for IoH applications.
- Developing blockchain-based IoH data management systems that offer transparency and security, reinforcing user trust.
- Conducting empirical studies on user perceptions of trust and privacy in IoH, providing data-driven insights to guide system design.

6.3 Inclusion and Engagement

Many IoH applications inadvertently exclude populations such as the elderly, persons with disabilities, or those from economically disadvantaged communities, due to a lack of accessibility and inclusive design practices [46]. Thus, further research studies are required as follows:

- Integrating inclusive design principles into IoH development processes, ensuring equitable access regardless of users' physical, cognitive, or socio-economic circumstances.
- Evaluating existing IoH services through user-centric participatory design methods, involving diverse user groups actively in system development and evaluation.
- Investigating AI-driven accessibility features (e.g., natural language interfaces, voice-activated control, adaptive user interfaces) tailored explicitly for broader, more inclusive user engagement.

6.4 Policy, Regulation, and Governance

The rapid evolution of IoH technologies has outpaced the development of coherent governance frameworks and regulatory policies, which is essential to balance innovation with ethical, legal, and societal concerns as described in [47]. Consequently, further investigation is needed in the following areas:

- Developing regulatory frameworks and ethical guidelines for IoH deployment, focusing on transparency, accountability, and ethical data handling.
- Engaging interdisciplinary research collaborations involving policymakers, legal experts, technologists, and ethicists to ensure comprehensive governance strategies.
- Establishing cross-border regulatory collaborations to create unified international standards that accommodate the global nature of IoH technologies.

6.5 Socio-Economic Impact and Adoption

Lastly, understanding socio-economic factors influencing the adoption of IoH is critical. As mentioned in the studies of [48], barriers related to cost, infrastructure, literacy, and social acceptance can hinder widespread adoption. Therefore, potential research directions include the following:

- Conducting socio-economic analyses and surveys to better understand user needs, adoption barriers, and the impact of IoH technologies in diverse socio-economic contexts.
- Designing scalable IoH solutions specifically aimed at resource-limited settings to demonstrate viability and effectiveness.
- Investigating economic models that support affordable and sustainable IoH solutions, thus facilitating broader adoption and acceptance.

Table 1 present the summary of the key challenges and possible research areas in the context of IoH.

7 Conclusion

The exponential growth and evolving complexity of internet technologies have significantly advanced the emergence of concepts such as IoT, AI, etc. However, in

Table 1 IoH challenges and future research directions

Key challenges	Potential research directions
Interoperability	Universal standards, Middleware solutions, Case studies
Privacy and security	Privacy-preserving tech, Blockchain-based solutions, Empirical user studies
Inclusion and engagement	Inclusive design principles, User-centred participatory methods, AI-driven accessibility
Policy and governance	Regulatory frameworks, Interdisciplinary collaborations, Cross-border regulatory standards
Socio-economic Impact	Socio-economic surveys, Scalable solutions, Sustainable economic models

this rapid technological evolution, human-centric considerations have frequently been overlooked. Most current systems are predominantly designed from technical and operational perspectives, often neglecting critical human factors such as user behaviour, trust, security, privacy, and inclusivity. These persistent challenges have emphasized the need for a novel, human-focused paradigm—the Internet of Humans (IoH).

The IoH concept, as explored in this paper, emphasizes two complementary perspectives. First, it advocates incorporating human-centric considerations directly into the design and development phases of innovative technologies, ensuring these systems align effectively with actual human behaviours, preferences, and requirements. Second, IoH urges the proactive integration of human needs, socio-economic factors, and ethical standards into future technological advancements, promoting inclusive, secure, and trustworthy internet solutions.

By comprehensively addressing the concept of IoH, this paper fills a significant gap in existing literature, clearly defining IoH, highlighting relevant enabling technologies, articulating key human-centric factors, and exploring potential application domains. The insights and detailed recommendations provided herein lay a robust foundation for future research, particularly regarding IoH adoption challenges, interoperability, policy implications, inclusive technology design, and standardization. Consequently, this study not only enhances the current understanding of IoH but also establishes a clear pathway for further scholarly exploration and practical development in this vital field.

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