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Review ***Article***

Internet of Senses Potential Applications and Implications

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ABSTRACT

The Internet of Senses (IoS) is an emerging field that aims to enhance human-machine interaction by enabling individuals to experience the digital world with their senses. This article, which explores a highly novel research topic, is at the forefront of Ericsson engineers' investigations, providing pioneering insights into the subject matter. IoS employs technologies such as virtual and augmented reality, haptic feedback, and olfactory and gustatory systems to provide multi-sensory experiences. This article provides an overview of the latest trends and innovations in IoS, highlighting its potential for human well-being and progress as well as the challenges that need to be addressed to ensure its safe and ethical implementation. The article also emphasizes the role of 6G in enabling IoS and the potential benefits of incorporating the chemical senses into digital technology. Overall, the IoS has the potential to revolutionize human-machine interaction and create immersive digital experiences.

1. Introduction

The IoS is a concept that represents a futuristic vision of a world where humans and machines are seamlessly connected, creating a new level of interaction between people and their environment. The idea behind this concept is that our senses are our primary means of experiencing the world around us, and technology can enhance and extend these senses beyond their natural limitations. With the IoS, individuals can have digital sensory experiences that closely resemble real-life experiences, creating a more immersive and sensory-rich world. The IoS integrates various technologies, including visual, audio, haptic, and others, to extend human senses beyond the limitations of our physical bodies. This innovation allows for heightened senses of vision, hearing, touch, and even smell, providing a new way for people to interact with digital content. Imagine being able to feel the texture of a fabric or the temperature of a surface through a screen, or even smell the aroma of a dish being prepared on the other side of the world.[1] The IoS has the potential to revolutionize the way we interact with technology and each other. However, with this level of connectivity comes new challenges and ethical considerations that must be addressed to ensure the safety and privacy of individuals. As we move towards a more interconnected world, we must ensure that the data being collected through these technologies is protected and used ethically. Moreover, the seamless integration of our senses with technology also raises questions about the impact on our physical and mental well-being. It is crucial to consider the potential consequences of this level of connectivity and address them before fully implementing the IoS. The future of the IoS is interdependent with the Metaverse, a virtual world where users can interact with each other and digital objects in a fully immersive way [2]. The relationship between these technologies is symbiotic, with each one augmenting the capabilities of the other.

The introduction of 6G as a connecting link

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facilitates the creation of immersive digital experiences that seamlessly integrate multiple sensory modalities. With the IoS, we can create a fully immersive, multisensory environment that revolutionizes our digital experiences [2].

Technology has significantly aided the conversion of our senses into digital formats, equipping us with instruments to record, scrutinize, and recreate stimuli from our surroundings. This capability empowers both people and machines to recognize and react to these stimuli. However, current devices primarily rely on audiovisual media and lack the ability to capture and stimulate the senses of smell, taste, and touch. To achieve a complete convergence of the physical and digital worlds, which is expected to be the next stage of the Internet, technology needs to cater to the chemical senses and associated stimuli.

2. Potential of the IoS and the Future of 6G Networks

The olfaction and perfume industries have significant potential, as highlighted in a recent report by MIT, which indicates that the global perfume industry currently generates a staggering $71 billion in revenue. [1,2] Hence, it is imperative that the development of new technologies include the ability to capture and simulate the chemical senses, thereby enhancing the user experience and expanding the possibilities of digital technology. [1,2]

Designers and developers may find value in research that explores the potential for touch, taste, and smell in human-computer interaction. This research introduces new ways of discussing taste and related experiences, and it could provide opportunities for more meaningful use of these senses. Often, people describe their experiences with taste using simple terms such as "I like it" or "it's sweet," but these descriptions do not convey the underlying properties of the experience, which can be important for designers to understand. By developing a framework that includes more detailed descriptions, such as "it is lingering," designers can create a more nuanced vocabulary and facilitate interesting discussions about interaction design. [1,2]

The upcoming 6G networks are expected to provide a significant boost to various areas. The design of 6G is centered around four main use cases, namely: connected intelligent machines, a digitized and programmable world, a connected sustainable world, and the IoS. The IoS is a concept that involves providing multisensory experiences that are almost indistinguishable from reality by using visual, auditory, haptic, olfactory, and gustatory stimuli. This is aimed at enhancing human-machine interaction and improving the overall experience.

The term IoS was coined by Ericsson, and it aims to provide immersive experiences that are almost indistinguishable from reality while increasing the interaction between humans and machines. This is achieved by using visual, auditory, haptic, olfactory, and gustatory stimuli in virtual and augmented experiences [3].

Ericsson (2016) suggests that the IoS may emerge by 2030, enabling direct access to the Internet space through the interface provided by our brains.[3] While this vision may seem utopian, it is possible that IoT devices will evolve into the IoS, which would allow humans to sense the world through a digital sixth sense that complements the traditional five senses. ZTE Corporation (2020) presents a more practical perspective on IoS as a pervasive technology that could be enabled by future 6G networks.[4]

The IoS has become a key area of interest for the development of future 6G technology, with major telecommunications companies such as Ericsson and ZTE Corporation exploring its potential [3, 4]. However, the realization of an IoS-enabled scenario will require significant advancements in global communication networks, including the ability to handle increased traffic and provide massive data capacity.

3. IoT And 6G/7G

The network services are scheduled for an upgrade, moving from 6G to 7G, which will introduce improvements to our way of life and the automation of daily tasks through IoT.[5] The energy spectrum utilized by 6G surpasses that of 5G. While 6G is considered satisfactory for securing smart homes, it may not fully address the security and privacy concerns. Moreover, there is a growing demand for 6G/7G devices in healthcare, particularly for network-enabled medical gadgets, as they offer various applications in the healthcare sector. [6] Figure 1 depicts the evolution of cellular communication, illustrating the increase in our internet speed and the significant leap with the future emergence of 6G and 7G.

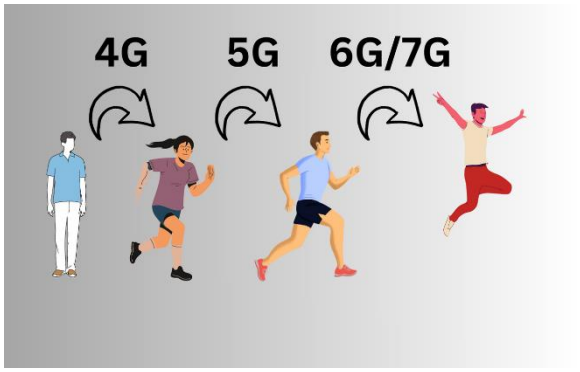

Figure 1 Evolution of Internet

In the realm of IoT-enabled smart transportation, the integration of connected cars and smart sensors embedded in bridges presents novel solutions to address daily challenges such as heavy traffic and limited parking space.[7] The integration of mobile edge networks in IoT-enabled smart devices is revolutionizing connectivity by providing enhanced access to AI, SDN, and IoT capabilities. The upcoming 6G network, slated for launch by 2030, is set to capitalize on advanced sensor technologies embedded within smart products [8].

This technological advancement has paved the way for a range of innovative devices, including smart refrigerators, washing machines, televisions, and other household appliances, as well as wearable gadgets like smart shoes and phones. However, it is imperative to prioritize addressing the security concerns associated with IoT-enabled applications to safeguard user safety and protect sensitive data [9].

Numerous IoT deployments encounter unique security challenges [10]. It is essential to address these hurdles in terahertz communication and prioritize the security of IoT products and services. The security aspects of IoT are addressed by the advancements brought forth by 6G/7G technologies.[11] The terahertz communication frequency band, ranging from 100 GHz to 10 THz, is being utilized in the era of 6G to 7G. This previously untapped frequency range offers limitless possibilities without any inherent limitations [12].

4. Mobile Communication Systems of 6G&7G

4.1. Communication Systems of 6G

The future 6G mobile system, designed for worldwide coverage, will incorporate both the existing 5G wireless mobile system and a satellite network. This satellite network comprises three key components: a telecommunication satellite network, an Earth imaging satellite network, and a navigation satellite network. The telecommunication satellite network will be responsible for voice, data, internet, and video broadcasting services, while the Earth imaging satellite network will focus on collecting weather and environmental information. Lastly, the navigation satellite network will enable the Global Positioning System (GPS) functionality. These satellite systems have been independently developed by different countries. The United States is responsible for the creation of the GPS, China has developed the COMPASS system, the European Union has introduced the Galileo system, and Russia has developed the GLONASS system.[13] As evidenced in Table 1, each successive generation of cellular technology, ranging from 4G to the emerging 7G, exhibits significant advancements in frequency bands, services offered, data rates, and other specific characteristics, highlighting the ongoing evolution of mobile communication technologies.

Table 1 Each generation of cellular technology, from 4G to 7G, advancements in Frequency, Services, Data Rates, and other specific information [14].

Parameters	Cellular Technologies			
	4G	5G	6G	7G
Frequency	2GHz-8 GHz	4G Frequency	95GHz-3THz	95GHz-3THz
Service	Wi-Fi, VoIP, LTE, WiMAX	Worldwide Wireless Web	Secured And Global Cellular Services	Secured And Global Cellular Services
Multiplexing	Orthogonal Frequency Division Multiple Access	All With AI Capabilities, Multiple Input Multiple Output, Code Division Multiple Access	Code Division Multiple Access	Code Division Multiple Access
Switching Type	Packet Switching (All Packer)	Ipv6 But Advancements Are Still To Be Done	All Packet	All Packet
Core Network	Internet	Internet	Internet	Internet
Data Rate	100-300 Mbps	About 100+Mbps	About 11 Gbps	About 11+Gbps
Advantages	Speed, High Speed Hand Offs, MIMO Tech, Global Tech	Better Coverage Area, Low Battery Consumption, Availability of Multiple Data Transfer Path, Energy and Spectral Efficiency Is More and Has a High Security	Global Coverage System	No Issue of Data Capacity Coverage and Low Cost of Call
Disadvantages	Hard To Implement, Complicated Hardware Required	The process and research on its viability are still ongoing. Achieving it is challenging due to inadequate technological support in many parts of the world. Developing the necessary infrastructure is costly, and security and privacy concerns remain unresolved.	Difficulty For Space Roaming, High Cost of Mobile Call and Similar With 5G Disadvantages	Similar With 5G And 6G Disadvantages
Location Of First Commercialization	South Korea	South Korea	Not Yet	Not Yet

4.2. Communication Systems of 7G

The 6G and 7G mobile network aims to provide global coverage while incorporating satellite functionality for mobile communication. [Table1] Within the satellite system, telecommunication satellites will facilitate voice and multimedia communication, navigational satellites will enable global positioning systems (GPS), and earth imaging satellites will provide additional information such as weather updates [13]. The 6G mobile wireless network will support local voice coverage and various services. However, the realization of 7G poses certain challenges that require further research, including seamless mobile phone usage during transitions between countries, considering that satellites also move at constant speeds within specific orbits. Additionally, standards and protocols need to be established for cellular-to-satellite and satellite-to-satellite communication systems. The ultimate realization of 7G can only be achieved once all these standards and protocols are defined. It is possible that these advancements may be realized in subsequent generations beyond 7G, potentially referred to as 7.5G.

5. IoS Definition

The IoS has emerged as a new frontier in the realm of human-machine interaction, focusing on the sensory aspects of sight, smell, mind, taste, touch, and sound. [Figure2] It refers to a concept where people can experience the digital world with their senses, using technologies like virtual and augmented reality, haptic feedback, and olfactory and gustatory systems. IoS promises to blur the boundaries between the physical and digital worlds, offering new possibilities for communication, entertainment, and education.

In recent years, IoS has witnessed significant developments, driven by advances in sensor technologies, data processing, and artificial intelligence. However, the reliability of IoT is a concern, and there are problems in the process of utilizing it [15]. Therefore, more research is needed to explore the potential of the IoS and IoT in different areas, including social interaction, healthcare, and environmental monitoring.

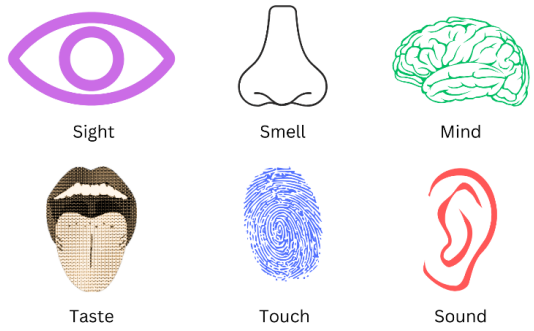

Figure 2 Senses of Body

6. Usage Areas on The Senses

The IoS has the potential to revolutionize the way we live, work, and interact with the world around us. Here are some of the potential applications and implications:

- Enhanced entertainment and media experiences: The IoS can create immersive and interactive entertainment experiences, such as virtual concerts, gaming, and movies.
- Improved healthcare and wellbeing: The IoS can improve healthcare outcomes by enabling remote monitoring, diagnosis, and treatment of patients, as well as enhancing the quality of life for people with disabilities and sensory impairments.
- Enhanced learning and education: The IoS can create personalized, and immersive learning experiences that stimulate multiple senses, making it easier for students to retain information and learn complex concepts.
- Increased productivity and efficiency: The IoS can enhance productivity and efficiency by providing real-time feedback and insights that help workers make better decisions and perform tasks more efficiently.
- Ethical and social implications: The IoS raises important ethical and social implications, such as privacy concerns, the potential for addiction and overstimulation, and the possibility of creating a society that is too reliant on technology.

6.1. Touch-Enabled Internet

The tactile internet refers to the ability to remotely access, monitor, and control objects or processes with haptic feedback, all in real-time [16]. A prime example of this technology is remote surgery, where haptic and audiovisual signals are transmitted from a remote location to a surgeon. With the use of immersive 3D HTC or XR video streaming techniques, the surgeon can interact with holograms or wear head-mounted VR glasses to receive audiovisual monitoring. The tactile internet has been extensively researched and is a compelling use case for the IoS, which aims to transform digital experiences into fully immersive, multisensory ones.

6.2. Trackable Personal Health

In the realm of the IoS, healthcare is an area that could greatly benefit from the use of connected sensors. By placing sensors on a patient's body, healthcare providers can remotely monitor vital health parameters such as blood pressure and heart rate. These sensors can be part of a larger sensor network, allowing for remote monitoring and timely intervention in emergency situations. Figure 3 seamlessly brings together the patient tracking system and Digital Senses under the IoS framework, creating an illustrative image for healthcare monitoring and management. Additionally, patient medical history can be recorded and stored for easy retrieval and use. Once these sensor networks are connected to the internet, medical professionals from around the world can collaborate and make real time decisions regarding critical health cases [17,18].

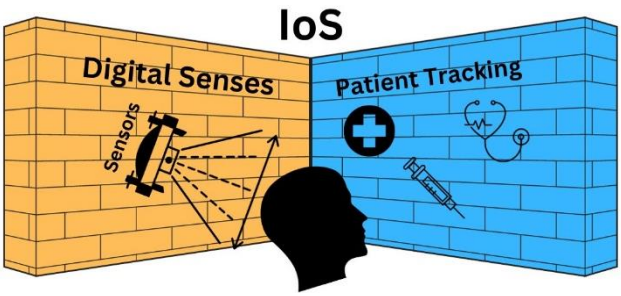

Figure 3 IoS for Patient Tracking

6.3. Education with Senses

The IoS has the implicit to revise the education sector. IoS is an arising technology that enables commerce between the real and virtual worlds by integrating the mortal senses into digital systems. By bedding detectors in objects and integrating pall computing, stoked reality, wearable technologies, and big data, different parameters of the educational

terrain can be measured and anatomized to give useful information [19]. IoS can be used to enhance the quality of higher education by providing a more interactive and personalized learning experience, where students can engage with the course material using multiple senses. Therefore, more research is needed to explore the potential of IoS in education and to develop models and criteria for its implementation.

6.4. Smart Manufacturing

Smart manufacturing empowers factory managers to collect and analyze data automatically, leading to better-informed decisions and optimized production processes. This strategy revolves around the gathering and utilization of data, which offers insights into "what to do" and "when to do it". The use of IoS technology in smart manufacturing enables real-time monitoring and remote management of processes, leading to improved outcomes such as reduced waste, faster production, and better-quality goods. This technology facilitates the smooth flow of data from sensors and machines to the Cloud, where it is analyzed and combined with contextual information before being shared with authorized stakeholders. The adoption of IoS technology in manufacturing is expected to continue growing in the future, leading to even greater improvements in production processes and outcomes [20].

7. Ethics of IoS

The implementation and deployment of an "ethical" framing in IoT devices or services may come at an additional cost, but it can lead to a higher level of individual freedom and choice. This added value justifies the extra expense and is likely to attract users who prioritize ethical considerations, potentially creating a specific market for such products [21]. It appears that the aforementioned situation in the IoT will persist in future technologies such as the IoS, given the increasing prominence of ethical concerns and the growing importance placed on them by users. When considering how a standard such as this intersects with those whose data is at stake, challenges arise. The common solution is to use an "end user license agreement" (EULA), which specifies the details of the agreement. However, there are two immediate problems with EULAs. Firstly, they tend to be excessively detailed and filled with technical and legal jargon, making them difficult to comprehend for many users. Secondly, the length and density of these documents often result in users not reading them and simply clicking through to make them disappear [22]. To prevent the occurrence of such situations, there is a need for further research on the ethics and applications of the IoS, in a more comprehensive manner.

8. Conclusion

The findings of this review suggest that further research is needed to fully understand the potential benefits and limitations of the interventions discussed. The IoS represents a futuristic vision that has the potential to revolutionize the way we interact with technology and each other. This innovation integrates various technologies, including visual, audio, haptic, and chemical, to extend human senses beyond the limitations of our physical bodies. With the ability to provide multisensory experiences that are almost indistinguishable from reality, The IoS strives to elevate the interaction between humans and machines, with the goal of enhancing the overall user experience. However, to ensure the safety and privacy of individuals, new challenges and ethical considerations must be addressed as we move towards a more interconnected world. Moreover, it is crucial to consider the potential consequences of this level of connectivity and address them before fully implementing the IoS. The development of new technologies that include the ability to capture and simulate the chemical senses will enhance the user experience and expand the possibilities of digital technology. Advanced technology networks, including 6G and beyonds are expected to provide a significant boost to various areas, including the IoS, but their realization will require significant advancements in global communication networks, including the ability to handle increased traffic and provide massive data capacity. Overall, the IoS represents an exciting. Opportunity for designers, developers, and researchers to explore new ways of discussing taste and related experiences and facilitate interesting discussions about interaction design. It is important to note that the IoS is a highly innovative and nascent field, which is why the research in this area is still limited. Given its novelty, there is a significant scope for further exploration and

investigation to fully comprehend and unlock the potential of this cutting-edge technology in transforming our sensory experiences and shaping the future of human-machine interaction.

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