

PAPER

From Metaverse Myth to Augmentiverse Reality: AR Smart Glasses and Standards-Led Convergence for Interoperability and Spatial Computing

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This study aims to provide a comprehensive assessment of the current state and near-term trajectory of augmented and immersive ecosystems, synthesizing progress across key dimensions of interoperability, identity, and hardware innovation. The analysis extends the “Augmentiverse” framework—an Augmented Reality (AR)-first, standards-aligned precursor to a broader Metaverse—by integrating tangible, real-world developments in AR smart glasses and head-mounted displays. It further situates these developments within the emerging paradigm of *spatial computing*, where digital content is persistently anchored to physical environments through shared standards and environmental understanding. The study examines how cross-industry coordination across XR runtimes (OpenXR, WebXR), 3D asset/scene interchange (glTF, OpenUSD via AOUSD), decentralized identity (W3C DIDs and Verifiable Credentials 2.0), immersive media (OMAF), and future network capabilities (IMT-2030) provides the essential foundation for a persistent, interoperable digital layer. Evidence from major technology firms including Meta’s strategic hardware ladder (Ray-Ban Meta Glasses, Oakley Meta HSTN, Meta Ray-Ban Display Glasses, and Orion) and the broader competitive landscape featuring Apple, Samsung, and Microsoft demonstrates that a pragmatic, staged approach is the most viable path to population-scale adoption. The central contribution of this research is a detailed, standards-first roadmap that operationalizes this vision, explaining how the convergence of lightweight, socially acceptable eyewear with robust open standards reduces fragmentation, strengthens user trust, and creates immediate economic value, thereby paving a realistic path toward deeper immersion as foundational technologies mature.

KEYWORDS

Augmentiverse, Metaverse, Augmented Reality (AR), AR Smart Glasses, Interoperability standards, Spatial computing, OpenXR and WebXR, Decentralized Identity (DID), Verifiable Credentials (VCs), Edge computing for AR

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1 INTRODUCTION

The notion of a global, interoperable metaverse has captivated the collective imagination, moving from the realm of speculative literature to a substantial interdisciplinary engineering initiative. While this vision has driven substantial investment and technical progress, the current landscape remains highly fragmented [1], [2]. Contemporary digital platforms frequently manifest as segregated “walled gardens”, inhibiting the fluid transference of user identity, rights, and digital assets among various vendors, devices, and contextual frameworks [3]. This paper reframes the discussion through a pragmatic, standards-led approach and advances the “Augmentiverse”, an Augmented Reality (AR)-first, real-world-anchored trajectory, as the most credible pathway forward.

The central thesis is that a viable, persistent digital continuum will not emerge from a single, all-encompassing virtual world but will instead be built incrementally. The hardware component is the most prominent and essential stratum of this technological evolution. Lightweight AR smart glasses and headsets are increasingly serving as the practical front end of this vision, delivering eyes-up, context-aware computing that enriches daily life without demanding prolonged, isolating immersion. These devices, which integrate with the physical world rather than replacing it, exemplify a user-focused and commercially viable pathway to an expansive immersive future. In our research, we argue that this hardware-led evolution is inextricably linked to the maturation and adoption of a robust, open standards framework. The synergy between a pragmatic device strategy and a standards-aligned foundation is what will ultimately transform a fragmented ecosystem into a coherent, future-ready Augmentiverse that paves the way for the Metaverse.

2 METHODS

This analysis is based on a narrative scoping review that prioritizes authoritative outputs from recognized standards development organizations (SDOs) and supplemented by corroborating evidence from industry reports and official announcements. Inclusion criteria for standards and frameworks emphasize those that have reached normative specification, recommendation, or a mature charter status, indicating material progress in areas critical to interoperability, identity, or media capabilities. Our methodology also incorporates a focused review of recent hardware prototypes, product announcements, and hands-on demonstrations from major technology firms. This supplementary data serves a crucial purpose: to provide concrete examples of how theoretical standards and frameworks are being implemented and to validate the strategic direction of the industry. Information from this review is used to establish the real-world state of adoption, market positioning, and the challenges associated with commercialization and large adoption.

3 THE PRACTICAL FRONT END: AR SMART GLASSES AND HEADSETS

The most credible path to mainstream spatial computing runs through AR smart glasses and pragmatic head-mounted systems that deliver eyes-up, context-aware experiences without requiring prolonged immersion. This aligns tightly with the Augmentiverse thesis, which emphasizes enriching the physical world rather than substituting it. The strategic decisions of major technology companies reflect this understanding, revealing a clear ladder of product evolution from simple eyewear to true augmented reality.

3.1 The Augmentiverse on your face: A pragmatic device ladder

Recent product releases and high-profile prototypes reveal a deliberate, staged hardware strategy. This strategic framework recognizes that the realization of a genuinely omnipresent AR apparatus necessitates extensive refinement over an extended temporal duration; consequently, it promotes a gradual approach that standardizes the form factor and cultivates a user demographic progressively. The first step on this ladder is consumer-friendly smart AI eyewear, as exemplified by the Ray-Ban Meta smart glasses and the Oakley Meta HSTN glasses. These devices established a mainstream baseline for hands-free capture, audio, and on-device assistant capabilities at an accessible price point of \$299. Their normalization of the form factor is a foundational step, priming the market for more advanced capabilities. At Meta Connect on August 17–18, 2025, the company unveiled the second generation of its Ray-Ban smart glasses: Meta Ray-Ban Display¹, marking a major step forward in wearable technology. Unlike the previous version, this new model integrates a built-in display and introduces a wide range of advanced functionalities designed to enhance both utility and style. With these improvements, Meta demonstrated its vision of merging everyday fashion with cutting-edge AR experiences. Their strategic positioning is to seed the market with the first display-equipped consumer smart glasses and to begin accumulating real-world usage data, particularly around neural wristband gestures, to inform future development. The aspirational top of this ladder is the “Orion” prototype², a device that showcases what “true AR” glasses could feel like a few years from now. Orion features micro-LED projection, a wide field of view, and a sophisticated wrist-worn neural interface for subtle sEMG input³. Independent hands-on reporting highlights the significant leap in optical performance and makes transparent the immense challenges remaining, including high prototype costs and the need for further miniaturization [4].

3.2 The competitive ecosystem: Catalysts and market segmentation

The AR/XR market is not a single, unified race but a strategic bifurcation. Apple’s Vision Pro launched a new narrative around “spatial computing,” anchoring the high-end of the market with a device focused on high-fidelity interaction. Its emphasis on enterprise workflows, productivity, and professional applications has set a new technical benchmark [5]. While its current form factor and price point target mainly prosumers and enterprise clients, its pioneering technologies are expected to trickle down over time.

The partnership between Samsung, Google, and Qualcomm represents a concerted effort to build a competitive ecosystem. With Google I/O 2025 remarks confirming

¹ Meta Ray-Ban Display smart glasses are set to go on sale starting September 30 for \$799. This price includes the glasses and the Meta Neural Band. Key features of these glasses include a high-resolution, full-color display built into the right lens that appears only when needed. The glasses are capable of showing: Text messages and video calls from apps like WhatsApp and Messenger. Visual results from queries to Meta’s AI service. Turn-by-turn directions for pedestrian navigation. Live captions and translations. <https://about.fb.com/news/2025/09/meta-ray-ban-display-ai-glasses-emg-wristband/>

² <https://about.fb.com/news/2024/09/introducing-orion-our-first-true-augmented-reality-glasses/>

³ Initially introduced as available only on the Orion AR glasses (still at the prototype stage), the neural band has since been extended to the Ray-Ban Display, as announced during Meta Connect on September 17–18, 2025.

the upcoming launch of their first Android XR headset, the consortium signals a multi-vendor push to establish an alternative platform [6]. On October 22, 2025, Samsung Electronics “unveiled Galaxy XR, introducing a new category of AI-native devices designed to deliver immersive experiences in a form factor optimized for multimodal AI. As the first product built on the new Android XR platform developed together by Samsung, Google and Qualcomm Technologies, Galaxy XR showcases the future of discovery, play and work, enabling users to enjoy natural, deeply immersive experiences (from daily tasks to bold new frontiers). It’s the first step in Samsung’s long-term XR journey, with innovations to come across the full spectrum of XR form factors, including AI glasses” [7].

As rapid advancements by companies such as Meta and Apple, Sumsung and Google are reshaping the market, HoloLens 2 and Magic Leap (which used to be the leaders in the domain of AR and XR) found it increasingly difficult to compete in terms of both technical innovation and integration into enterprise workflows. Ultimately, high costs, ergonomic shortcomings, technical limitations, and strategic pivots led to the discontinuation of both devices in late 2024 (see Table 1).^{4,5}

Table 1. XR/AR/MR platform comparison

Platform/Product	Primary Form Factor	Strategic Market	Key Innovation	Reported Pricing (Approx.)
Meta’s Ray-Ban Smart Glasses	Smart glasses (Audio/Camera)	Consumer-first	Integrated Meta AI, hands-free capture (12MP/3K video), open-ear audio	\$299–\$379
Meta Quest 3	Mixed-reality headset	Consumer/Gaming	Full-color passthrough, Snapdragon XR2 Gen 2, pancake lenses	\$499
Meta Ray-Ban Display Glasses	AR Display Glasses	Consumer/Productivity	High-brightness micro-LED display, lightweight AR overlay	\$799
Meta Orion	AR glasses prototype	R&D/Long-term vision	Wide FOV, Micro-LED display, neural interface (concept)	Five-figure prototype cost
Apple Vision Pro	Mixed-reality headset	Prosumer/Enterprise	Micro-OLED ultra-high resolution, eyes-hands-voice interaction (visionOS)	\$3,500
Samsung Galaxy XR	Mixed-reality headset	Partner-led ecosystem	High-res Micro-OLED displays, open Android XR stack, Snapdragon XR2+ Gen 2	\$1,799.99
Microsoft HoloLens 2	Mixed-reality headset	Industrial/Regulated	Mature MR stack, verified workflows, waveguide optics	~\$3,500
Magic Leap 2	Augmented Reality headset	Industrial/Regulated	Dynamic dimming, improved field of view, lightweight optics	~\$3,300

⁴ HoloLens 2 and Magic Leap failed to achieve widespread success for several reasons. High prices made these devices inaccessible to most consumers and burdened even enterprise budgets, with HoloLens 2 costing around \$3,500 and Magic Leap 2 around \$3,300. Ergonomic challenges and the bulkiness of both headsets limited comfort and long-term wearability, making them impractical for all-day use. Additionally, the limited field of view and sometimes underwhelming display quality failed to deliver fully immersive experiences, especially as competitors introduced more advanced passthrough and AR technologies. https://www.reddit.com/r/microsoft/comments/1fu58z6/microsoft_is_discontinuing_hololens_2_as; <https://learn.microsoft.com/en-us/answers/questions/2151213/microsoft-stops-hololens-2-production-support-to-e>; <https://www.thevrra.com/news2/2024/11/21/recap-of-our-hololens-is-dead-long-live-orion>

⁵ <https://www.businessofbusiness.com/articles/heres-why-magic-leap-failed-to-make-ar-a-consumer-product/>

3.3 The primacy of interaction: From air gestures to neural interfaces

User input and interaction are paramount for the mass adoption of AR devices [8]. For a device to be truly ubiquitous, the social cost of interaction must be minimized, a significant challenge in public spaces, where voice commands or mid-air gestures are often impractical or socially awkward [9].

The emergence of new input modalities, such as neural wristbands that use subtle sEMG (surface electromyography) signals, represents a foundational innovation for the Augmentiverse. This technology, prominently exemplified in Meta's Orion prototype and then integrated into Meta Display Glasses, reads electrical impulses from the forearm muscles that control the hand and fingers. It has the capability to identify even minuscule or conceptual motions that are imperceptible to onlookers, converting them into accurate digital directives.

By enabling accurate, private control without large gestures or audible cues, sEMG-based interaction drastically reduces the social friction associated with AR use in public environments. This quiet, minimal form of input directly supports the development of socially acceptable AR eyewear and is critical for transforming AR from a technology used in isolation into one that integrates seamlessly into daily public life.

4 THE CORE PILLARS OF THE AUGMENTIVERSE

While hardware provides the tangible front end for the Augmentiverse, its success depends entirely on a robust, open, and interoperable standards-based foundation (see Table 2). These standards act as scaffolding, preventing the ecosystem from devolving into a fragmented collection of proprietary silos [10].

Table 2. Key standards and frameworks for the Augmentiverse

Standard/Framework	Sponsoring Body	Primary Function	Contribution to Augmentiverse
OpenXR 1.1 & WebXR	Khronos Group, W3C	Cross-platform XR runtimes & browser APIs	Reduces developer fragmentation; enables unified codebase for native & web experiences
W3C DIDs & Verifiable Credentials 2.0	W3C	Portable, privacy-preserving digital identity	Establishes a trust fabric for portable identity, entitlements, and provenance
glTF & OpenUSD	Khronos Group, Alliance for OpenUSD	3D asset & scene interchange	Ensures content portability and interoperability across toolchains
ISO/IEC 23090-2 (OMAF)	ISO/IEC	Omnidirectional media delivery	Enables scalable, low-latency streaming of immersive content
IMT-2030 (6G) & Edge	ITU-R, Industry	Next-generation network capabilities & localized compute	Provides the long-term network foundation; enables responsive, low-latency experiences today

4.1 Runtime and 3D Web

The foundational layer of the Augmentiverse is a crucial runtime environment designed to solve platform fragmentation, allowing developers to create experiences not locked to a single device or ecosystem. This is achieved through two complementary standards: OpenXR for native applications and the WebXR Device API for browser-based content.

For native applications built with engines such as Unity and Unreal, OpenXR provides an essential abstraction layer. Developed by the Khronos Group, this royalty-free, open standard acts as a universal translator between an application and the device's specific hardware drivers.⁶ Previously, developers had to maintain separate codebases for each manufacturer's hardware. With OpenXR, they write to a single, standardized API, allowing one application to run seamlessly across a diverse range of headsets by interpreting head tracking, controller inputs, and haptics uniformly. This significantly reduces development costs and ensures content can reach the widest possible audience.

In parallel, the WebXR Device API serves the same unifying purpose for experiences delivered through a web browser. This API grants web pages secure access to the input and output capabilities of virtual and augmented reality devices. This allows developers to build rich, immersive 3D worlds using familiar web technologies such as JavaScript and WebGL that are accessible via a simple URL.⁷ The power of WebXR lies in its immediacy, as users don't need to download and install an application from a proprietary app store. This frictionless entry is vital for casual engagement and the overall growth of immersive content. Together, OpenXR and WebXR form a robust foundation that champions an open, cross-platform future for both developers and users.

4.2 Identity and credentials

For an immersive ecosystem to be truly interoperable, user identity and entitlements must be portable and verifiable. W3C decentralized identifiers (DIDs) v1.0⁸ and verifiable credentials (VC) 2.0⁹ are essential, providing cryptographically provable identifiers and a standardized framework for privacy-preserving credentials [11]. The resulting "trust fabric" is capable of traversing vendor boundaries. This technical foundation supports self-sovereign identity (SSI) [12] a model where digital identity ownership and management reside solely with the individual, not with external entities such as companies or governments.

4.3 Assets and scene interchange

For any open and connected immersive environment (such as virtual worlds, metaverse platforms, or 3D digital spaces) to work properly, digital content must be able to move freely between different platforms and systems.

glTF 2.0 is a commonly used standard that lets 3D models and assets (like objects and characters) be easily shared and used across many different applications and platforms. The Alliance for OpenUSD (AOUSD) is an organization working to establish a main standard (specification) for how whole scenes-collections of objects, lighting, cameras, and their relationships, are described and shared between tools and platforms. These standards are crucial because they enable the "create once, use

⁶ <https://www.khronos.org/openxr/>

⁷ <https://www.w3.org/TR/webxr/>

⁸ DIDs let users have digital identities that are cryptographically secure and controlled by the user, not a central authority.

⁹ VCs provide a standardized way to issue and share credentials or proofs (like proof of age, membership, etc.) that protect the user's privacy.

everywhere” capability for 3D content, which is fundamental for achieving a truly open and interoperable 3D ecosystem.

4.4 Immersive media delivery

To show stable, always-there digital information (overlays) on lightweight AR Smart glasses smoothly, you need to deliver media (like video or graphics) very efficiently. This is especially important because these glasses usually have limited internet bandwidth and weaker processors than bigger devices. The standard ISO/IEC 23090-2:2023, also called OMAF (Omnidirectional Media Application Format), defines a way for different devices to share and stream 360° or VR media in a way that’s compatible across many systems. The Open Media Application Framework (OMAF) endorses sophisticated streaming methodologies, such as tiled streaming (transmitting exclusively the segments of a video or scene that the user is currently observing) and viewport-aware streaming (allocating computational resources to elements within the user’s visual field). These methodologies guarantee the seamless delivery of high-fidelity, immersive overlays to AR Smart glasses without imposing excessive demands on the device’s bandwidth or processing capabilities. This is key to making digital overlays practical and enjoyable on lightweight wearable technology.

4.5 Connectivity and edge compute

A fully realized, population-scale metaverse requires networks capable of delivering ultra-low latency and high reliability so that data can be transmitted with almost no delay [13]. The ITU IMT-2030 framework for 6G sets the long-term trajectory for achieving these performance targets at scale, but today’s lightweight AR glasses remain constrained by limited battery capacity and thermal budgets, forcing them to offload computation to external infrastructure. When unprocessed sensor information is transmitted to remote cloud servers, round-trip latencies may attain several hundred milliseconds, exceedingly excessive to preserve immersion, as even minimal delays disrupt the synchronization between digital augmentations and the tangible environment. This renders cloud-exclusive processing inadequate for uninterrupted augmented reality functionality, particularly as device dimensions persist in decreasing.

In the near term, edge computing provides the pragmatic bridge toward the ultra-low-latency vision outlined in IMT-2030. By placing compute resources closer to the user, at the network edge or within the base station, edge-assisted processing shortens physical data-travel distance and significantly reduces latency for AR workloads [14], [15]. Research indicates that this methodology not only enhances responsiveness but also has the potential to reduce round-trip times from cloud-scale latencies to approximately 10 milliseconds or less, a benchmark that is critical for stable and synchronized augmented reality experiences. Lightweight AR glasses that depend on offloading therefore rely on edge delivery to maintain real-time performance [16], with the reduction in delay (ΔL) enabling smooth, reliable operation despite their hardware limitations.

5 THE AUGMENTIVERSE ROADMAP: FROM THEORY TO PRACTICE

The Augmentiverse is not a speculative construct but a tangible, standards-aligned roadmap. The convergence of hardware innovation and open standards creates a self-reinforcing ecosystem. A staged hardware strategy generates real-world user data and usage patterns, which in turn validate the importance of standards for inputs and identity. A developer can invest in building an application that leverages OpenXR and W3C DIDs, confident that their work will be compatible with a growing range of devices. This staged, standards-aligned path is both user-centered and ecosystem-centered, creating immediate economic value while building the social norms and technical foundations required for a more immersive future.

6 SOCIETAL IMPLICATIONS

The proliferation of wearable AR systems engender a diverse societal challenge that goes beyond mere technical implementation. Researchers consistently insist on an urgent necessity to address the significant ethical, privacy, security, and human rights dilemmas that accompany this technology [17], [18]. Despite the establishment of various policy frameworks, design principles, and technical mitigations to address these concerns, they remain in an embryonic phase of development, necessitating immediate and proactive engagement from researchers, developers, and policymakers alike [19].

6.1 Privacy, consent, and data agency

This unremitting flow of data makes it exceedingly difficult for individuals to maintain comprehensive cognizance of, let alone exercise authority over, the information that is being collected and analyzed at any particular moment in time. In contrast to conventional digital interactions, which allow for consent to be obtained for discrete actions, AR devices perpetually aggregate data from a multitude of sensors (e.g., cameras, microphones, inertial measurement units), thereby complicating the framework of meaningful informed consent. This continuous flow of data renders it unfeasible for individuals to maintain comprehensive awareness of, let alone exercise control over, the information that is being collected and processed at any particular moment.

This dilemma is further intensified by the inherent threat to third-party privacy, as these devices are compelled to capture data related to individuals who are not users and situated nearby, often without their awareness or consent [20]. The frameworks employed for data acquisition and processing that are critical for the functionality of augmented reality concurrently present novel vulnerabilities that may result in breaches of privacy. Given these apprehensions, scholars propose the incorporation of privacy-enhancing techniques (PETs) at the foundational architectural stratum, in conjunction with a transition towards localized edge processing. By conducting the processing of raw sensor data either on the device itself or via a local edge server, the risk of exposing sensitive information to potentially insecure cloud infrastructures can be markedly diminished [21].

6.2 Surveillance, sousveillance, and data sovereignty

Augmented reality systems constitute powerful mechanisms that can enable pervasive observation by both governmental and corporate entities, thereby producing extensive documentation of individuals' lives, movements, and interpersonal engagements. Simultaneously, they cultivate a phenomenon of sousveillance, or citizen monitoring, in which citizens may record one another, potentially eroding social trust and the principles of public anonymity.

The bifunctional nature inherent in surveillance elicits profound inquiries regarding the proprietorship of data and the notion of sovereignty. Who has the authority to access, control, and profit from the massive datasets generated by augmented reality experiences: the user, the hardware maker, the app developer, or society as a whole?

The ambiguity surrounding these matters has prompted calls for a vigorous public discourse and the formulation of precise legal frameworks to delineate data rights and allowable uses, hence ensuring that the technology does not evolve into a mechanism of unregulated monitoring [20], [22].

6.3 Security vulnerabilities in distributed AR architectures

The computational requirements associated with real-time augmented reality frequently necessitate the delegation of data processing tasks to distant cloud or edge computing servers. This distributed framework, albeit essential for optimizing performance, engenders considerable security vulnerabilities pertaining to data storage, access controls, and real-time integrity (Diyora and Khalil, 2024). An adversarial entity could feasibly intercept, manipulate, or compromise the data stream, which could yield dire repercussions, encompassing the misappropriation of sensitive personal information as well as the malicious modification of a user's perceived reality.

In order to mitigate these threats, study underscores the imperative for the adoption of robust, end-to-end security protocols. This encompasses the implementation of rigorous encryption for data both in transit and at rest, secure authentication mechanisms, and the advancement of resilient edge architectures specifically engineered to accommodate the low-latency, high-throughput requirements of AR workloads while withstanding tampering and unauthorized access [15].

6.4 Ethical transgressions and social harms

Beyond privacy and security, wearable AR presents a spectrum of ethical and social risks. A primary concern is the potential for the deceptive manipulation of reality, where digital overlays could be used to spread disinformation, alter perceptions of events, or emotionally manipulate individuals. Furthermore, the AI models that power AR content generation and interaction are susceptible to biases present in their training data, which fact can lead to discriminatory model behavior, reinforcing societal stereotypes or creating inequitable experiences for different demographic groups.

On a practical level, the immersive nature of AR poses distraction-related safety harms, where a user's attention is diverted from their physical surroundings, leading to accidents [24]. Finally, inequitable access to expensive AR technology threatens to amplify digital inequality, creating a new "reality divide" between those who can afford its benefits and those who cannot, thereby exacerbating existing social and economic disparities [20], [22].

6.5 Governance frameworks and interoperability

In order to make AR evolve into a cohesive and functional component of a future metaverse, a robust foundation of interoperability, shared ethical standards, and cross-platform governance is essential. In fact, without a proactive and collaborative effort to establish common protocols, the AR landscape risks fracturing into a collection of proprietary, "walled-garden" ecosystems. Such fragmentation, reminiscent of the early, closed online services before the open internet, would not only stifle innovation by increasing development costs but also fundamentally undermine user agency. It would trap users' data, social graphs, and digital identities within single platforms, severely limiting their freedom, control, and ability to move between services [22].

The literature, therefore, strongly advocates for the collaborative development of comprehensive governance models designed to foster an open ecosystem. Establishing these frameworks proactively is crucial for building a healthy, competitive, and user-centric environment [25]. This involves progress on several key fronts:

Technical interoperability: This requires the standardization of core technologies, including file formats for 3D assets (e.g., glTF, USD), protocols for spatial mapping, and schemas for avatar and identity representation. Technical interoperability ensures that a user's digital assets and persona are not locked to a single platform but can be seamlessly ported across different AR applications and services, promoting competition and user choice.

Data portability and sovereignty: Beyond technical standards, a governance framework must enshrine the principle of data portability, giving users the explicit right and technical means to extract their data (including social connections, created content, and interaction histories) from a platform. This empowers users and aligns the AR ecosystem with modern data protection principles. Advanced theoretical frameworks even advocate for decentralized identity architectures, wherein users, rather than platforms, possess and govern their fundamental digital identity.

Normative and ethical alignment: An operational metaverse necessitates a collective comprehension of permissible behavior and content. Governance structures must formulate normative frameworks to address urgent issues, including harassment, misinformation, and harmful content within AR environments. This imperative calls for a collaborative multi-stakeholder methodology, integrating platform administrators, scholarly researchers, civil society entities, and end-users to jointly delineate and implement community standards that safeguard individuals while honoring the principles of free expression.

7 RECOMMENDATIONS

The analysis of current hardware trajectories and standards development provides a clear roadmap for stakeholders invested in building an open and interoperable immersive future. The following recommendations are offered to operationalize the Augmentiverse framework for key groups within the ecosystem.

For software engineers and creators, the foremost challenge is the fragmentation of ecosystems. To alleviate this issue and optimize application accessibility, developers ought to prioritize OpenXR 1.1 and the WebXR Device API as the default runtime environments. Embracing these standards permits a singular codebase to cater to a diverse range of both current and forthcoming devices, encompassing high-end headsets as well as lightweight eyewear. Concurrently, innovation in user interaction is paramount. Developers are encouraged to design for low-friction, “eyes-up” interaction models that minimize social cost, moving beyond conspicuous air gestures to explore subtle input modalities inspired by emerging technologies like neural wristbands, which promise more private and socially acceptable control.

For leaders in product and strategy within technology enterprises, the evidence strongly counsels against a singular, comprehensive approach to the development of the metaverse. Instead, it is imperative that they implement a phased, incremental strategy for hardware that advances from rudimentary, socially accepted smart eyewear to authentic augmented reality capabilities over time. This “device ladder” methodology serves to standardize the form factor, cultivate a user base, and generate vital real-world usage data which can guide subsequent development efforts. The strategic emphasis ought to be placed on essential, high-value use cases that enhance the physical environment rather than supplanting it, such as heads-up navigation and glanceable assistance. This approach is in accordance with the Augmentiverse thesis and provides immediate, concrete value for consumers, thereby establishing a sustainable trajectory towards deeper immersion.

As for those engaged in ecosystem development, encompassing standards development organizations (SDOs), industry consortia, and contributors to open-source initiatives, the paramount objective is to avert the fragmentation of the digital ecosystem into proprietary “walled gardens.” These entities must diligently engage in, advocate for, and realize a collective foundation of open standards. This endeavor entails the promotion of W3C (DIDs) and verifiable credentials (VCs) to forge a portable and privacy-conscious trust framework for user identity. Furthermore, it is of equal importance to propel standards such as glTF and OpenUSD to facilitate the seamless exchange of 3D assets and dynamic digital twins, in addition to OMAF for the effective transmission of immersive media to devices with limited resources. By constructing and sustaining this shared framework, these organizations guarantee a more competitive, innovative, and user-focused future.

8 CONCLUSION

In this paper, we argue that the most viable and immediate pathway to a persistent, interoperable digital layer is not through the pursuit of a singular, all-encompassing virtual metaverse, but through a standards-first “Augmentiverse” anchored in the physical world. The analysis of the current landscape reveals a clear and pragmatic trajectory, defined by two convergent forces.

First, a staged hardware evolution led by major technology firms is normalizing AR form factors through progressively more capable AR smart glasses, prioritizing user-centric, context-aware experiences over full immersion. Second, a maturing framework of open standards (spanning runtimes such as OpenXR, identity protocols such as W3C DIDs, and 3D asset formats such as OpenUSD) is providing the essential scaffolding to prevent ecosystem fragmentation and ensure interoperability.

The primary implication of these findings is that hardware innovation and open standards development are engaged in a self-reinforcing cycle that operationalizes the Augmentiverse roadmap. Socially acceptable AR hardware drives mainstream adoption, generating real-world usage patterns that, in turn, validate and inform the creation of standards for everything from subtle user input to decentralized identity. This synergy transforms a fragmented market into a coherent ecosystem, creating immediate economic value while building the technical foundations and social norms required for a more immersive future. It is of paramount importance that the dependence of lightweight devices on Edge Computing for the delegation of processing tasks highlights the pressing necessity for the establishment of next-generation network standards. Research demonstrates that edge-assisted processing is essential to reduce the delay, ΔL , from cloud-scale latencies to the critical 10 milliseconds or less benchmark required for stable and synchronized Augmented Reality experiences [14].

We can't deny that this study is not devoid of limitations. As a narrative review based on publicly available specifications, industry announcements, and reports, it lacks insight into proprietary corporate research and is subject to the rapid pace of technological change. Furthermore, the examination of profound societal implications (from privacy in an era of continuous sensing to the governance of personal digital twins) remains at a high level and warrants deeper, dedicated investigation. Future research should therefore pursue several key avenues. Quantitative investigations are imperative to evaluate user acceptance of diverse augmented reality form factors and the effectiveness of innovative input modalities. Additionally, further technical examination is essential to establish benchmarks for the performance of edge computing architectures in the synchronization of digital twins on a large scale. Finally, critical socio-technical research is essential to develop robust governance frameworks for data ownership and decentralized identity in a world where the lines between the physical and digital are increasingly blurred.

In closing, the Augmentiverse is not a speculative construct but an emerging reality being built today. The convergence of lightweight, world-aware hardware with a robust, open framework for identity, assets, and connectivity offers the key to unlocking the next era of computing. This pragmatic, standards-aligned path promises to deliver a future where a persistent digital layer is not a distracting myth, but a seamless, integrated, and value-creating part of our daily lives.

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