

Quality of Experience in the Metaverse: An Initial Analysis on Quality Dimensions and Assessment

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Abstract—The Metaverse provides a novel experience to the user, by opening the doors to social-based multiuser environments merging physical reality with digital virtuality. In this paper, we present an initial analysis of the Quality of Experience (QoE) in the Metaverse. We first consider traditional influence factors (human, system, and context). Then, we introduce the social and economic dimensions of the Metaverse as additional factors to be considered for QoE assessment. Finally, we discuss what QoE assessment methods can be more suitable for Metaverse applications, with a particular focus on implicit assessment methods (e.g., physiological, human cognitive, affective behaviour).

Index Terms—Metaverse, Quality of Experience, Social dimension, Economic dimension, Implicit QoE assessment.

I. INTRODUCTION

The Metaverse is defined as “the post-reality universe, a perpetual and persistent multiuser environment merging physical reality with digital virtuality. It is based on the convergence of technologies that enable multisensory interactions with virtual environments, digital objects and people, such as virtual reality (VR) and augmented reality (AR)” [1]. There are different types of Metaverse, such as gaming-based (e.g., Roblox, Second Life, Minecraft, Fortnite, Pokemon Go) or blockchain-based (e.g., The Sandbox or Decentraland). Some Metaverse (e.g., Horizon of Meta) are totally based on VR technologies and require a VR headset to immerse the user in the virtual world. However, all Metaverse have in common one element, i.e., providing a virtual world where people can interact with the digital environment and other users in real-time. Nonetheless, with respect to AR and VR, the Metaverse has a strong aspect as a service with more sustainable content and social meaning [2]. Therefore, the social dimension has a crucial role for the Metaverse applications.

Since it is an emerging application, there are not studies in the literature that investigated how to evaluate the Quality of Experience (QoE) in the Metaverse. However, similarly to other multimedia-based applications, the QoE definition

provided by the QUALINET White Paper can be considered valid also for Metaverse applications as the starting point for the analysis: “the QoE is the degree of delight or annoyance of the user of an application or service which involves an immersive media experience” [3]. This White Paper also defines the human, system, and context influence factors (IFs) as the main factors potentially impacting the QoE of the users of an application or service. Based on these White Paper definitions, in [4], an overview of different IFs and dimensions that may affect the overall QoE of interactive VR applications is provided. The QUALINET group has also presented a White Paper specifically focused on immersive media experience [5]. Immersion and sense of presence are particularly relevant QoE features contributing to the quality perceived by the user in VR and AR applications [4]. These QoE features allow to evaluate, respectively, the degree to which the range of sensory channel is engaged by the virtual simulation [6] and the sense of being in the virtual world [7]. Thus, QoE studies focused on the experience perceived by using immersive applications are of extreme importance as the basis to assess the QoE of Metaverse applications. However, not all Metaverse are based on immersive technologies. Also, there are additional aspects that may impact on the user’s QoE, such as economic factors, engagement, and social involvement, which are of particular relevance for Metaverse applications.

In this paper, we first consider the traditional QoE IFs. Then, we introduce the social and economic dimensions of the Metaverse as additional factors for QoE assessment. Next, we discuss what QoE assessment methods can be more suitable for Metaverse applications and we provide final conclusions.

II. TRADITIONAL QoE INFLUENCE FACTORS

We consider the human, system, and context IFs as the main factors potentially impacting the QoE of the users of Metaverse applications [3].

1) *Human influence factors*: Regard both static (e.g., sex, age) and dynamic (e.g., affective state) information concerning the user. The affective state may be measured with the methods discussed in Section IV. When VR-based technologies are involved, discomfort symptoms, such as cybersickness, must also be considered to evaluate the overall QoE.

2) *System influence factors*: The system IFs concern the network infrastructure, the hardware, and the multimedia content. A solid network infrastructure is required as the baseline

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for supporting the Metaverse applications, in particular when high-resolution multimedia contents are involved (e.g., 360 video) [8]. In [9], the network architecture of the Metaverse is discussed, where the edge network is identified as a great support for offloading computations (e.g., multimedia rendering) for Metaverse applications to improve performance and enhance the end user's QoE. With regard to the hardware, the VR headset is an important element that influences the perceived quality because of its weight and screen quality. Hopefully, the VR headset manufacturers will be continuously improving the headset, making it wireless and lighter. The screen quality, in terms of image resolution and frame-per-second rate, is directly connected to the perceived QoE. Authors in [10] found that a 2K resolution is an important threshold for an enhanced VR experience without affecting performance and increasing sickness levels. Other hardware devices, such as motion inputs devices, hand-based input devices, haptic devices can also affect the quality of the Metaverse experience. Finally, multimedia contents also have a direct impact on the perceived QoE. Authors in [11] suggest that the users' visual attention is highly restricted as the VR sickness increases. Therefore, the visual attention loses the focus from the multimedia content, affecting at the same time the users' perceived quality. In [12], the impact of audio quality on gaming experience under different bitrate and packet loss conditions is investigated. Results highlight that: the packet loss affected both the audio quality and the gaming QoE; the sound genre can affect the gaming QoE.

3) *Context influence factors*: Regard all those factors that describe the user's environment in terms of physical, temporal, social, economic, task, and technical characteristics [3]. For instance, the influence of the surrounding environment is investigated in [13], where the subjects were exposed to different light and noise stimuli while consuming multimedia contents. The social aspect in gaming has been treated in [14], where the social context is represented by players' group composition based on previous player's gaming experience.

III. THE SOCIAL AND ECONOMIC DIMENSIONS OF THE METAVERSE

We identified two additional aspects that should be taken into account to assess the QoE of Metaverse applications: the social and economic dimensions of the Metaverse.

A. *The social dimension of the Metaverse*

In [2], it is highlighted that while VR-related studies focus on a physical world acquisition and digital rendering, the Metaverse has a strong aspect as a service with more sustainable content and social meaning. Also, it is stated that the Metaverse has a scalable environment that can accommodate many people, which is essential to reinforce social meaning. In [15], the MetaSocieties are defined and the Metaverse is described as a parallel world that runs in the exact moment as the real world. The authors state that the Metaverse expands the living and the working space for humans, allowing the humans to interact with each other in the virtual/real environment.

Even Facebook has changed name to Meta as it considers the Metaverse as the next evolution of social connection.

Therefore, the social dimension of the Metaverse is very important, and it is a unique characteristic that is not provided by other multimedia-based applications. Although the QUALINET White Paper considers the social factors within the set of the context IF, we think that the social dimension of the Metaverse is a quite different concept. Indeed, the social aspect considered for traditional multimedia applications mostly regards consuming the service alone or with other people. Current multi-user applications have a final goal and some subjects collaborate or *fight* to reach that goal (e.g., gaming). The social dimension in the Metaverse is a different concept as it regards sharing a digital place where people can interact or stay closer like the real world. For instance, a subject could go to a Metaverse place (e.g., a city, a shop, a pub, which can even be the digital *version* of a real place) where he can meet friends but also find unknown people he can interact to and merry the partner. This opens to the consideration of particular social aspects related to people behaviours in the virtual world: i) the users behaviour may be annoying or even aggressive toward other people. For instance, according to Meta, a beta tester was virtually groped by a stranger on Horizon Worlds. Further sexual assaults happened in the same Metaverse are reported in the SumOfUs report [16]. Such a behaviour may influence negatively the perceived QoE of the Metaverse; ii) users can have different attitude: they can decide to climb the social ladder of the Metaverse and become leaders of other people or they can decide to undertake a solitary experience of the virtual world by ignoring social interactions. Social aspects also regard how the user interact with other users. One-to-one and one-to-many interaction may happen in different ways, such as chatting, talking, or even gesture of the avatars. Also, the user has the opportunity to interact both with friends (from the real world) and strangers randomly met in the Metaverse. Thus, there is the need to define novel methods to assess how the social dimension of the Metaverse impacts the user's perceived QoE. This is not straightforward because the Metaverse is an uncontrolled environment utilized by other people (besides test participants) and it would not be easy to quantify the impact of specific aspects (e.g., social interactions) with controlled assessments. User profiling can be useful to lead the users to places and events of the Metaverse close to the user's interests by fostering meeting with new people with common interests so as to optimize the social experience in the Metaverse.

B. *The economic dimension of the Metaverse*

With regard to the economic dimension, again we think that it is a different concept from the economic factors defined in the QUALINET White Paper within the set of the context IFs. Indeed, the economic aspect considered for traditional multimedia applications mainly regards the price (tariff) paid to utilize the service. Instead, with the economic dimension of the Metaverse we identify the possibility to buy digital properties in the Metaverse, such as lands (virtual spaces), NFT

TABLE I
ASPECTS OF THE SOCIAL AND ECONOMIC DIMENSIONS OF THE METAVERSE THAT MAY INFLUENCE THE USER'S QoE.

Dimension	Aspects
Social	User behaviour: polite, rude, aggressive
	User attitude: solitary experience, leader or follower, interested in climbing the virtual social ladder
	User-user interaction: one-to-one, one-to-many, with friends, with strangers
Economic	Money: need of crypto-currency to buy virtual goods (e.g., virtual lands, virtual house, virtual clothes for the avatar)
	Job: user works in the Metaverse to earn crypto-currency

(non-fungible token), or virtual accessories for the avatar with specific digital wallets and crypto-currency. The economic dimension also includes the possibility for the user to find a job in the Metaverse and to earn money as well (crypto-currency in this case). Thus, the financial means of the user may strongly influence the perceived QoE of the Metaverse since some desired goods or services may not be affordable. Even some places may be not accessible. User profiling may be useful also for the economic aspects, such as to find an employment that requires the user's skills or to suggest events affordable for the user's financial means.

Table I summarizes the main aspects of the social and economic dimensions of the Metaverse discussed in this section.

IV. QoE ASSESSMENT

There are still no defined methodologies to assess the QoE of Metaverse applications, in particular with regard to the social and economic dimensions. We discuss advantages and drawbacks of subjective and implicit QoE assessment methods.

A. Subjective assessment

The subjective QoE assessment is the major approach to measure the user's perceived quality, since it considers the user's subjective experience, feelings and expectation. The most prominent method to assess the subjective QoE is to use single stimulus tests with ratings on a 5-point Absolute Category Rating scale (ACR). The average of the ACR scores (for stimulus) provided by the subjects is known as the Mean Opinion Score (MOS). This type of tests are usually organized in lab environments with standardized and controlled conditions. For instance, the QoE of 360 videos is assessed in [8], where the subjects had to rate the perceived QoE as well as further aspects, such as sense of presence, acceptability, and cybersickness. Emotions also play an important role in how people perceive and approach the virtual world around them and react to stimuli. In order to quantitatively measure emotions, the Self-Assessment Manikin (SAM) questionnaire [17] can be used, which considers three discrete, nine-class graphical rating scales for emotional dimensions, namely, valence, arousal and dominance. Often, the valence is found to be positively correlated with the perceived QoE [13]. Nonetheless, subjective assessments have major drawbacks: i) the need to ask explicit feedback to the user; ii) time and money consuming; iii) the rating scale may not reflect well the user's internal perception of quality.

B. Implicit assessment

As an alternative to subjective methods, implicit measurements (e.g., physiological, human cognitive, affective behaviour) can be used to objectively measure the perceived QoE. Physiological methods try to assess the perceived QoE implicitly by means of perceptual and cognitive processes (e.g., electroencephalography, heart rate) [18]. In [19], a VR assistive technology system based on physiological metrics is realized. Several parameters (i.e., electrodermal activity, heart rate, blood volume pressure, temperature, accelerometer, electroencephalogram) are used as indicators of the subjects' perceived QoE. Although physiological methods provide valuable insight into QoE of advanced media technologies, their utilization may currently be still invasive for the users and not suitable for real-time QoE evaluation. Nonetheless, there is another research field that has gained attention in the last years, i.e., the affective computing, which investigates the relationship between the human perceived QoE and affective behaviours driven by human emotions. The emotions can be automatically inferred from facial expressions, speech, and body gestures [20]–[22]. In [21], [23], facial expressions patterns and gaze directions of the user while watching videos were used to train a machine learning-based QoE estimator. The quality of remote working was estimated in [22] based on analysis of workers' speech features. Speech features were used to estimate the QoE also in [20]. Thus, these implicit methods can be used to infer the emotional state of the users, by means of their affective behaviors, while using Metaverse applications. This would: i) enable continuous unobtrusive monitoring of user's QoE; ii) avoid asking the user to provide feedback after/during the perceived experience. While several studies observed a correlation between the affective state and the QoE, further research investigations are needed to define precise QoE models based on these measurements.

V. CONCLUSION

We presented an initial analysis of the QoE in the Metaverse. It emerged that the social and economic dimensions of the Metaverse may have an important impact on the user's QoE. Social aspects include user's behaviours and interactions with other people as well as their social position in the Metaverse. Economic aspects include the need of financial means to afford goods and the job position in the Metaverse. We identified implicit QoE assessment methods as those more suitable to assess the user's QoE in the Metaverse continuously and unobtrusively. However, there is still much to research concerning the QoE assessment in the Metaverse and with

this proposed initial analysis we hope to inspire discussions and ideas for future studies.

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