The Research on a Cloud Intelligence Communication Platform of Smart Edge Devices Supporting for Metaverse Spatial Reality

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***Abstract*—This paper would like to introduce a new Device Edge Computing (DEC) that connects wearable devices with multimodal sensor hubs (supersensitive cameras, supersonic complex sensors, etc.) and (B)5G public/private networks. This DEC has studied the function/performance requirements of metaverse devices that support super-reality and super space-reality eXtended reality (XR) services that directly feel the high-sensitivity sensing of remote virtual objects, and proposes a quality-guaranteed cloud intelligent network architecture platform to support advanced services of metaverse space reality content.**

Keywords-DEC; Metaverse Wearable Devices; Spatial-Reality.

I. INTRODUCTION

Recently, in the non-face-to-face era such as COVID-19, we are actively researching and developing the "metaverse daily service" era that can remotely control the real and virtual objects ((Non-)IIoT vs. Avatar) by remotely connecting to a metaverse communication platform without going to a smart factory or smart farm, etc [1]. In addition, the advanced Information & Communication Technology (ICT) countries in the metaverse research field of communication, media, and content are actively providing virtual and reality space due to the development of ultra-high-speed, ultra-low-latency mobile networks, ultra-real media User Interface (UI) / User eXperience (UX), and the advanced Cloud-based Software Defined Network (SDN) / Network Functions Virtualisation (NFV) / virtual Deep Packet Inspection (vDPI), 5G/6G & Multi-access Edge Computing (MEC), Virtual Reality (VR), Augmented Reality (AR) / Mixed Reality (MR) / XR media and their ultra-immersive contents technology.

Currently, the main characteristics of metaverse-supported physical communication, media, and content for hybrid Brain Computer Interface (BCI) & XR services would be required as follows:

1) Measure and analyze various willingness and sentiment with multi-modal sensor detection of smart wearable device [4].
2) Recognize and respond to the environment-surrounding risk factors in advance through Big-Data and AI analysis.
3) Enhance and apply the collective intelligence communication through {body intelligence (brainwave & willingness & emotion) + hydrology Convolutional Neural Network (CNN) / Reinforcement Neural Network (RNN) / Spiking Neural Network (SNN) + Internet Cloud intelligence},
4) Acquire the determining system of situation, inference, simulation for ensemble of global heterogeneous signals through a multi-modal signal hub

So, we believe that metaverse services will be provided in the following short-term period, mid-term period, and long-term period forms in terms of applying the following metaverse scenarios:

Short-term period: In the event of an emergency, rescue workers at a disaster site, wearing augmented reality (AR/XR) glasses receive the emergency evacuating information from a remote location to safely rescue the victims via AR Tele-Presence/Navigation.

Mid-term period: A healthy running emotional exercise between couples living apart from Seoul and Jeju Island while feeling friendly remote five senses through the immersive spatial-reality AR/XR glasses and human intelligence edge devices as shown below in Fig. 1.

Figure 1. Metaverse Running Healthy with Remote Virtual Partners [Mid-term period]

Long-term period: Like Luc Besson's SF movie "Valerian: City of a Thousand Planets," a true metaverse service that connects to virtual space in a desert-like real space to experience the XR/hologram-type surroundings and main character movements

In the above service scenarios, the following specifications would be required for Metaverse Wearable UI/UX devices and their supporting DEC devices (Fig 2):

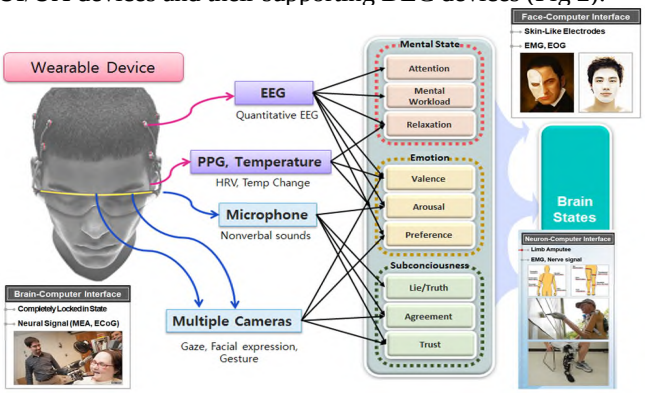

Figure 2. Metaverse Wearable XR Glasses

- Smart Thin-Client Wearable Device: {Social feed analysis (object feature point/area extraction accuracy: 65.0 APoks, Learning performance: 0.25sec) & AI-imaging (Cascaded R-CNN, Location/Area Detection Accuracy: 69.5/64.0%, 20fps, Similar Product Search Accuracy: 63.8%, Style Tag Extraction Accuracy: 73.85%)}, examples: UI/UX such as Electro Encephalo Graphy (EEG) helmet, AR glasses, XR goggles, AR interlocking ring/thimble, etc. [1]
- Smart Edge Devices: high-performance spatial scanning holographic camera/projection as an extension of WiFi-Access Point (AP) {Multi-View-Point 2D Web-Cam Scanner and ALG-motion (2+ people, up to 27 joints) motion recognition technology create 31.5-inch 8K glasses-free-3D Light Field (LF)-hologram realistic content}, Communication Intelligence On-device AI/Computing (AIoT), etc [1].

The remaining of the paper is structured as follows: The overall of Section 2 presents the Metaverse DEC Cloud Network Architecture and its required DEC's detail specifications in Section 2.A, 2.B, 2.C.

II. MAIN RESEARCH ISSUES

In section II, we would show the relationship of metaverse device and direction of cloud intelligence communication platform in II.A, and detailed research and developing direction of DEC cloud intelligence communication platform for Metaverse in II.B, and the future Metaverse services' challenges expecting functions & performances in II.C.

A. Relationship of Metaverse Device and Direction of Cloud Intelligence Communication Platform

In an ultra-low delay, high broadband, and ultra-connected intelligent communication environment under 5G/MEC [2] and 6G/DEC [6], the metaverse user devices would be advanced as listed in Table I.

TABLE I. MAIN CHARACTERISTICS OF METAVERSE USER DEVICES

Monitors (Notebook, Laptop etc.)	Smart Phones (Mobile)	Smart Glasses (VR-HMD Headsets) (AR/MR/XR-Glasses)	Vehicles (Automobile)	Metaverse Devices
Windows, MacOS	iOS, Android Studio	Unity, Unreal, ARcore etc (various contents SDKs)	ADAS studio	Meta-studio (digital hologram)
AR-Projection	AR-Tracking AR-Rendering AR-Mirroring	Unity XR-Stack & SOFA	AR-Projection (AR-Navigation etc.)	Open Meta-OS (SOFA++ digital twin)
		OpenXR (Open SmartGlasses-Device Standard I/F)	ADAS Device I/F	OpenMetaverse (Open 4GIR - standard device I/F)
WiFi connecting Tethered-Smartphones	WiFi/4G connecting (eMBB/mMTC/uRLLC slices) (Edge Cloud & Macro-Cell)	WiFi/5G connecting (eMBB/uRLLC slices) (Edge Cloud & Macro/Small-Cell)	5G communication (eMBB/uRLLC slices) (Edge Cloud)	6G/6E comm. (+bloackchain slices) (Device Cloud: DEC)

The AR/XR/hologram glasses, drone-attached intelligent five-sensory device edge computing (DEC) 4D, automatically adjusting 4D (3D+five senses) space size and visibility/light of indoor and outdoor environments, recognizing and identifying 4D (3D+five senses) metadata required to identify object information, we think that it is necessary to secure a new five-sense experience-type Spatial-Reality metaverse technology that connects virtual information about see-through objects reflected from remote locations by cluster control communication and synchronization only with gaze/speech/gesture-UI access.

It is necessary for supporting a complete thin-client communication structure between smart wearable devices [3][5] worn on the body and smart edge devices that support off-loading the insufficient network/computing /storage-caching performance of all-in-one wearable devices. It is thought that research on a "metaverse device communication platform that supports physical enhancement spatial-reality" that expands to five senses (such as visual/hearing/scent/taste/touch) and cloud intelligence is needed.

Therefore, this basic study will be conducted in the following directions as the below of Fig. 3:

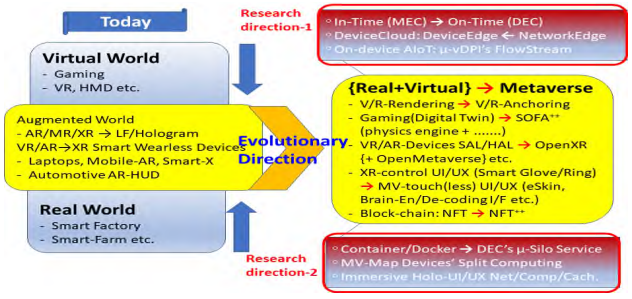

Figure 3. On-Premise DEC Study Direction (Red) according to Metaverse Evolution (Yellow)

- Research direction 1: The realistic immersive wearable device computing requires ultra-small, light-weight, and low-power AIoT(AI of Things) audio-visual intelligence that satisfies metaverse services: Indoor and outdoor real-world/object-cognitive and 3D-space correlation analysis/control method.
- Research direction 2: The real-time & time-sensitive deterministic multi-collaboration Visual Intelligent Device Edge Computing (DEC) with cloud intelligence communication platform structure that provides visual safety and visual work efficiency.

B. *Detailed Research and Development Direction of DEC Cloud Intelligence Communication Platform for Metaverse*

Prior to the metaverse era, VR/AR composite rendering support was simply a trend provided by Local Server (Thin-Client structure), but VR/AR support is gradually approaching MEC (Edge Cloud) in the 5G era. In the future, it is expected that it will be developed into a DEC for on-time provision of XR/Hologram next-generation XR contents beyond VR/AR. Therefore, the DEC concept is expressed in Device Cloud terms in 2021, and the establishment of the concept has not been clearly confirmed in international standardization. For the metaverse-support DEC R&D, this ETRI established domains in two directions for effective preemptive responses as in Fig. 4.

1) Cloud Intelligence Communication Edge Device Requirements & Specification based on Metaverse Service Characteristics: User Device Requirements & System Requirements - Definitions Established

2) The Platform of DEC Structure/Function/Performance of Cloud Intelligence Communication Edge Device based on Metaverse Service Quality Assurance

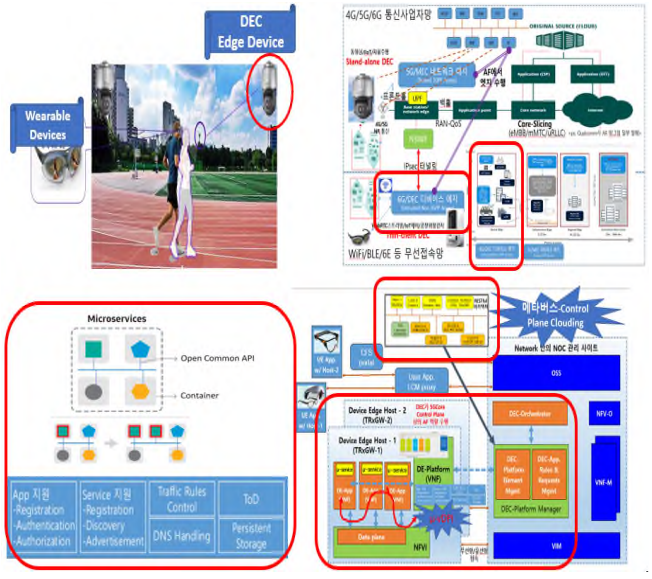

Figure 4. Cloud intelligence communication type DEC type of 5(6)G network application location/structure (red box)

C. *Future Metaverse Services Expect Functional/ Performance Challenges*

1) Edge Access-Point (AP) device requirements (Fig. 5)

- Visual Intelligent Edge Device-HardWare(HW)
  - 3D high-precision position/coordinate and size SLAM calculations, fixed/mobile/drone-attached variable-lightening, high-density resolution and motion-to-photon (HW-MTP), edge GPU/TPU/NPU (biological) chips & AP (Application Processor) boards
- Visual Intelligent Edge Device-SoftWare(SW)
  - Multi-Collaborative Virtual Space Infrastructure Dynamic Configuration, Real/Virtual Object Matching Precision, Eye-movement/Biological/Body-gesture Automatic Tracking and Situation Cognition, μ-Service Device-dedicated OS/SDK/IDE SW Development Environment
- Visual Intelligent Edge Device-AIoT
  - Real-object property correlation analysis, correlation matching with virtual objects, multi-collaboration spectrum optimization, real-time caching of device's location/gesture transformation content, real-time resource optimization, privacy of fixed/movement objects, etc
- Visual Intelligent Edge Device-Network Computing
  - Location/posture conversion Round Trip Time (RTT) ultra-low latency, Physical/Virtual/Container Network Function (PNF/VNF/CNF)-mixed micro-service silo structure with RESTful bus structure, DEC net computing virtualization with 5G-CorePlane AF(Application Function) and MEC standard model linkage, and Multicast/Broadcast support on XCF & XUF functional modules for multiple collaborations on 5G-CorePlane

2) Wearable Device Requirements Specifications (Fig 5)

Figure 5. ETRI Trustworthy AR Platform (an example)

- Analysis of the possibility of achieving 95% of the final metaverse (XR/SR) realistic recognition rate based on cognitive advancement (95%) in body (brain wave/biological) targets
  - Metaverse virtual space deployment time: 10 seconds → 1 second → 10ms or less
  - Metaverse {brain wave→real virtual object} directive response time: 1 second→10ms→1ms or less
  - Metaverse EEG-Intention/Emotional/Immersion Content: (Video) AR/XR→3D (real) Hologram→4D (feeling) Hologram
- (AR/VR/XR) Key features of wearable device requirements as Tele-Presence services evolve
  - Short-term period: Remote IoT-control Service in TR-Presence: Remote IoT access and cyan-tracking object-control based on Tele-Presence {Connected IoT access and simple gaze/voice reflected in mutual AR glasses between AR-DECs (Head Mounted Display (HMD) 100% already achieved)-Command control (HMD 100% already achieved) (HMD visualization RTT average 23ms achieved)
  - Mid-term period: Remote tactile (five senses) analysis/ transmission and fine-feeling (sense) object-control on Tele-Experience
  - Long-term period: Remote Thinking (intention, emotion) analysis and communication on Tele-Hologram and physical-AI-based all-thing (people/things)-control

III. CONCLUSIONS

Currently, this study is planning to establish a linkage structure between metaverse user devices, Device Cloud, 5G/MEC and 6G/DEC, derive a real/virtual-object content metaverse platform environment between 5G/6G Control Plane and wearable/edge devices, and identify metaverse content creation levels as shown in Fig. 6.

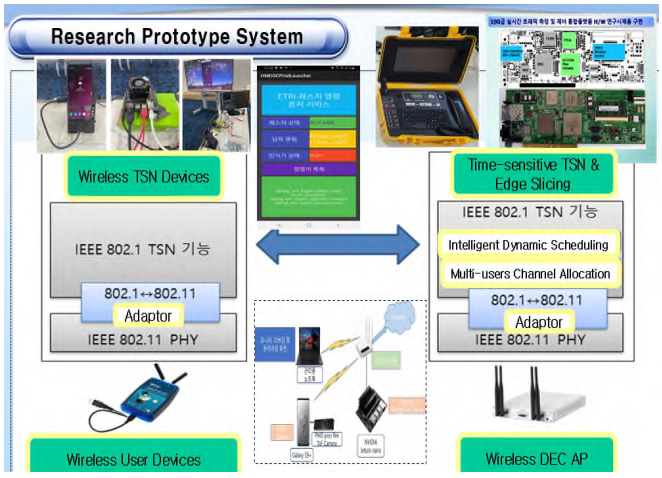

Figure 6. DEC Prototype Device & Server Platform (from ETRI & KoreaTech Univ.)

The results of this study will be a preemptive research opportunity in the development of intelligent edge device communication platforms that provide as follows (Fig. 7):

1) High angle, high precision, and xyz space coordinate 3D space risk detection and work efficiency in everyday life
2) A preemptive research opportunity for the development of an intelligent edge device communication platform that provides life safety audio/visual-moving_guide through recognition/ inference of the elderly/children's behavior observation.

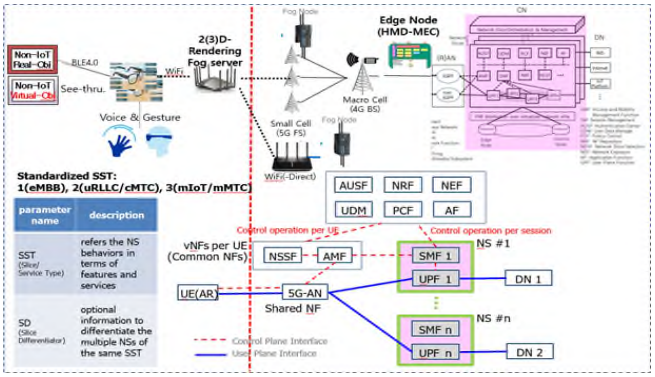

Figure 7. The DEC adapting to 5G Core Plane Prototype

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