



IOWN
GLOBAL FORUM

AI-Integrated Communications Use Case Release-1

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[AIC Use Case]

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Preface

The IOWN Global Forum is committed to the principles of data privacy and confidentiality. As an organization, we will work to ensure any potential use cases developed will respect individual privacy and not abuse access to confidential information. Individual service providers and other entities leveraging these use cases are responsible for protecting user data and keeping information private.

1. Introduction

Thanks to advancements in communication and computing technologies, the world has become smaller as technological advances have spurred new ways to connect with each other, new ways to work, new ways to enjoy entertainment, and new ways to approach old problems. The communications and computing infrastructure developed and deployed over the past 30 years have made these changes possible, but ever-increasing user demand and perpetual innovation threaten to tax the very infrastructure that has driven this unprecedented change. Moving forward, another quantum leap in computing and communication capabilities is necessary to give the world the infrastructure required to continue innovating and advancing its communications capabilities. The mission of IOWN Global Forum is to develop fundamental communication, computing, data, and energy efficiency technologies that will foster quantum leap performance improvements and enable a much smarter world with advanced applications, including those with digital twin computing.

The primary purpose of this document is to highlight some of the future-looking use cases that this infrastructure advancement would enable. In doing so, this document outlines application-specific service requirements that would benefit users from different vertical industries. The collection of requirements outlined herein will be used by the IOWN Global Forum and its members to develop technical recommendations for a long-term feasibility study focused on these use cases.

Use cases are categorized into human-centric applications to assist and enhance communication (AI Integrated Communications: AIC) and smart city applications that aim for autonomy beyond human capability (Cyber-Physical Systems: CPS). Two documents have been created to capture each category's different objectives and define a distinct set of requirements [IOWN GF, 2020].

2.Scope

The document intends to provide a key feature set and requirements for use cases categorized into AI-Integrated Communication.

The initial focus will be put into the following categories

- Entertainment
- Remote Operation
- Navigation
- Human Augmentation

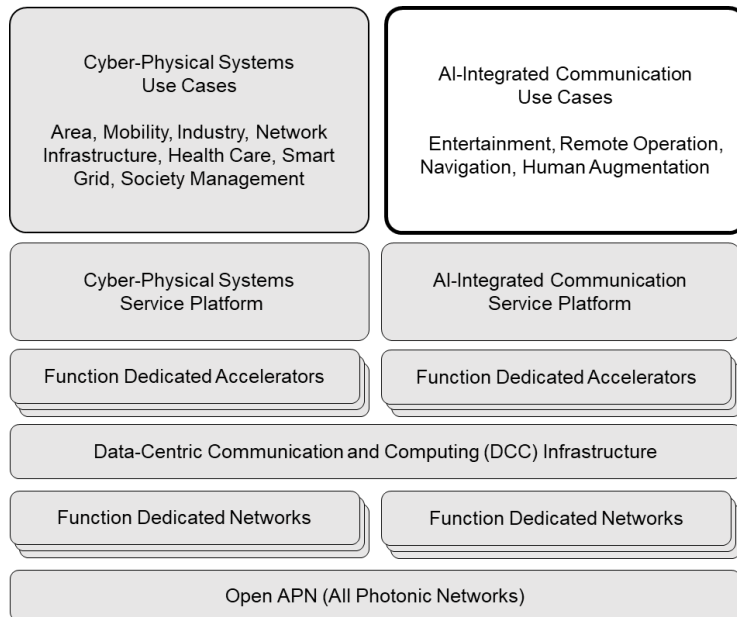


Figure 1 IOWN Global Forum – Work Item Structure

3. Use Case Details

3.1. Entertainment

Early efforts using current technology to create immersive entertainment experiences (such as VR events, holographic concerts, etc.) have met with mixed success. While this can, in part, be attributed to the novelty of the models, perhaps the most significant limiting factor has been the lack of the computing and communication infrastructure necessary to create a truly immersive experience for users. The technical advancements proposed by the IOWN Global Forum will pioneer new ways to deliver immersive entertainment regardless of the user's physical location. This section describes new use cases on the future of music, sports, and game entertainment.

3.1.1. Interactive Live Music

3.1.1.1. Description

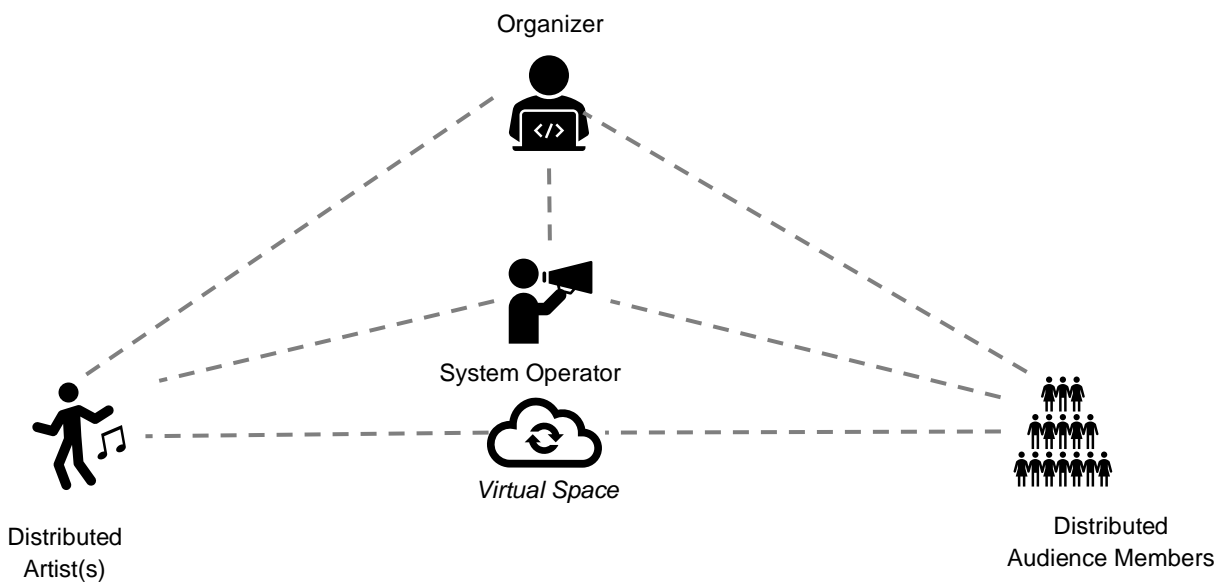


Figure 2 Overview of Interactive Live Music

IOWN will revolutionize how Audience Members enjoy live music performances. The Audience Members in their own homes or at karaoke boxes will have an immersive experience as if they were attending a concert in person. The technical advancements envisioned by the IOWN Global Forum will enable distributed Audience Members to experience a sense of energy and purpose of unity with other Audience Members as they cheer or sing along with their favorite Artist together. The distributed Artists will also have an unprecedented experience interacting more intimately with individual fans or even collaborating live with a remote Artist at a distant location.

The IOWN Global Forum, with its AI Integrated Network, will also change how live entertainment is conducted. The System Operator will be able to analyze in real-time the reaction of the distributed Audience and create a virtual stadium/hall with customized sound and visual effects that fit the atmosphere of the crowd. The System Operator will also track the QoS delivered to each Audience Member and dynamically allocate resources as needed. The Organizer will collect/analyze the big data gathered during the event to efficiently plan for future events.

The following Personas appear in this use case:

- Audience Member: People who are remotely watching and participating in a live music performance. Up to around 20,000,000 people.
- Artist(s): Person or group performing at the live music performance. Distributed Artists may be remotely located from one another.
- System Operator: Person or group operating the system of the live music performance.
- Organizer: Person or group organizing the live music performance.

3.1.1.2. Key Feature Set

3.1.1.2.1. Persona #1: Audience Member

As an Audience Member, I want to;

- Interact with the Artist
 1. View the live performance with high fidelity 360-degree free perspective video and audio
 2. Sing, sway, and dance along with the Artist
 3. Respond to the Artist to root and cheer

so that I can have an immersive experience as if I were at the concert stadium/hall.

- Interact with other Audience Members
 1. Cheer together and share the excitement with the other Audience Members and monitor how I am seen from the different Audience Members
 2. View the performance anywhere with multiple devices-e.g., TV, Screen, tablet, smartphone, HMD as I change location and switch devices accordingly

so that I can share exciting experiences with other Audience Members.

3.1.1.2.2. Persona #2: Artist

As an Artist, I want to;

- interact with the Audience Member
 1. see, hear, and feel the Audience Members behavior
 2. request for cheer, dance, sing

so that I can be as if I am at the stage at crowd filled stadium/hall.

- interact with other Artist(s)
 1. sing and play along with other members/performers
 2. dance and sway along with other members/performers

so that I can feel as if we are on the same stage.

- interact with the virtual space
- interact with the System Operator
 1. adjust feedback from the Audience Member-e.g., volume, view size, etc.
 2. pick a selected Audience Member to be highlighted

so that I can give a feel of exclusiveness to Audience Members.

3.1.1.2.3. Persona #3: System Operator

As a System Operator, I want to;

- monitor the state of the Artist
 1. location and direction regarding camera/mic position to select and create effects—e.g., ROI (Region Of Interest), lightning, etc., both manually and automatically
 2. video/audio quality provided toward the Artist to adjust and adapt operation mode
- monitor the state of the Audience Members
 1. engagement state of Audience Members to select and provide toward the Artist the feedback of excitement at the Audience Members
 2. video/Audio/Data quality provided to Audience Members to adapt operation mode
 3. video/Audio/Data quality provided toward the Artist to select appropriate feedback toward the Artist
 4. behavior of Audience Members to exclude him/her if he/she does not have an appropriate behavior in his/her interaction

so that I can give the best performance to Audience Members within the range of affordable costs.

- select the Artist scene to be used
- select the Audience Members' feedback to be used
- create a virtual space where Artists and Audience Members coexist and interact with overlaying natural and artificial images to give an immersive experience to both Artists and Audience Members.
- cancel the Artists' and the Audience Members' echo to highlight Artists and specific Audience Members.

3.1.1.2.4. Persona #4: Organizer

As an Organizer, I want to;

- collect behavior of the Artist during the event
 1. interaction toward the Audience Members
 2. interaction toward the other Artists
- collect the behavior of the Audience Members during the event
 1. interaction toward the Artist
 2. interaction toward the other Audience Members
 3. other interaction over the network
- analyze the collected data

so that I can enhance and reflect on subsequent events.

3.1.1.3. Service Gap/Requirements

- Immersive virtual space creation: Bandwidth/latency is not enough to collect images, sound, and sensor data from Artist and Audience Members. Computational power is limited to create an immersive virtual environment in a real-time fashion

- Immersive virtual space distribution: Bandwidth/latency is not enough to distribute personalized virtual space data toward large-scale distributed Audience Members. Also, the means to synchronize images, sound, and sensor data from Artist and Audience Members within the required latency are lacking
- Data Analysis platform: No sufficient means to collect data in a consolidated manner, including Artist-to-Audience Member, Audience Member-to-Artist, Audience Member-to-Audience Member. In addition, data transaction toward the cloud (virtual space) and data transactions made in P2P both need to be considered

Service requirements can be summarized as follows;

- number of Audience Members: ~20,000,000
- raw data rate at the Artist: 90 ~ 230 Gbps
 - Note: the data rate depends on the emulated distance from the eye to the object (1m@120fps: 230 Gbps, 3m@90fps: 90 Gbps)
- latency
 - interactive/synchronous components: ~10 msec
 - synchronous Sound: ~20 msec
 - non-verbal communication (e.g., waving hands): ~100 msec
 - verbal communication: ~300 msec
- end-to-end QoS across wired/wireless connectivity
- data synchronization within the required latency

3.1.2. Interactive Live Sports

3.1.2.1. Description

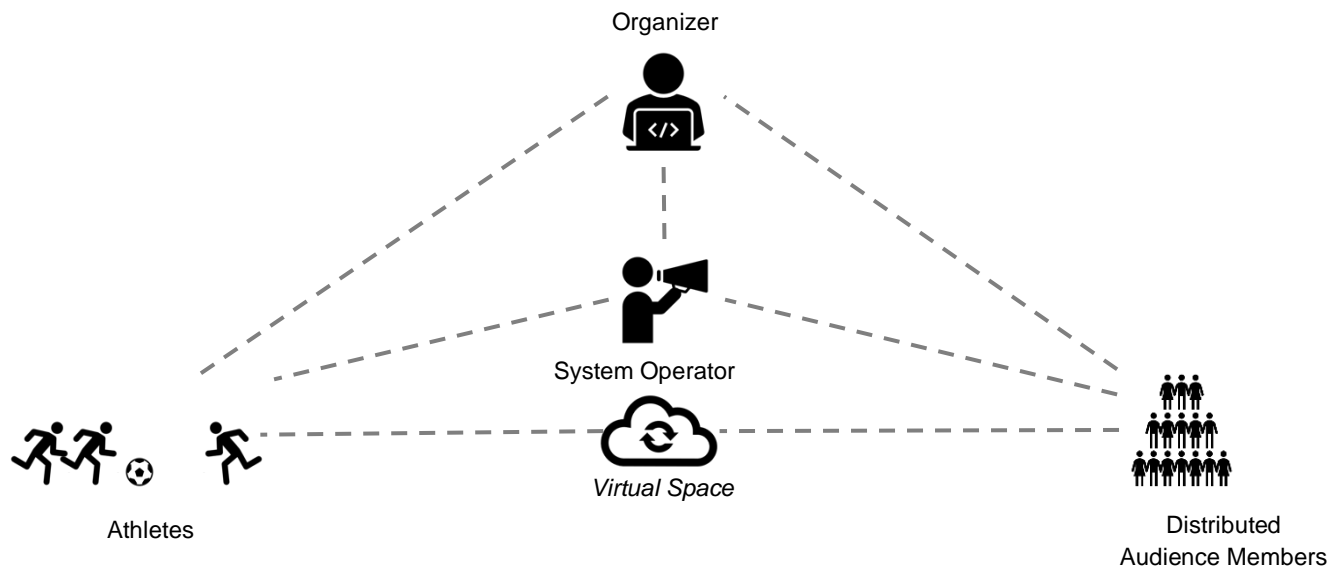


Figure 3 Overview of Interactive Live Sports

As with Interactive Live Music, there have been some early efforts to create immersive, distributed experiences around live sports events, mainly using VR or multiple screens. Ultimately, the sheer number of variables and accommodating the viewing preferences of potentially millions of viewers requires a leap in computing performance and bandwidth to bring immersive experiences to fruition.

The IOWN Global Forum will develop requirements and recommendations that, when implemented, will change how distributed Audience Members view live sports events. The distributed Audience Members in their own homes, at a sports bar, or a public screening venue will have an immersive experience as if they were at a stadium/arena, viewing the athletes' performance in high-quality video and audio from any seat of their liking. The distributed Audience Members will experience a sense of unity with the other Audience Members by chanting together for their favorite team or cheering together in joy when a goal is scored. The athletes will also have an unprecedented experience in interacting more intimately with individual Audience Members. The IOWN Global Forum, with its AI Integrated Network, will also change how live sports event is conducted. The System Operator will be able to analyze in real-time the reaction of the distributed Audience Member and create a virtual stadium/arena with customized visual and sound effects that fit the crowd's atmosphere. The System Operator will also be able to keep track of the QoS delivered to each Audience Member and automatically and dynamically allocate resources as needed. The Organizer will be able to collect/analyze the big data gathered during the event to efficiently plan for future events.

The following Persona appears in this use case;

- Audience Member: People who are remotely watching and participating in a live sports event.
- Athlete(s): Person or group performing at the live sports event.
- System Operator: Person or group operating the system of the live sports event.
- Organizer: Person or group organizing the live sports event.

3.1.2.2. Key Feature Set

3.1.2.2.1. Persona #1: Audience Member

As an Audience Member, I want to;

- Interact with the Athlete(s)
 1. view the Athlete(s) with high fidelity 360-degree free perspective video and audio
 2. playback a highlight (e.g., a goal scene) of the Athletes' performance and Athletes' view
 3. send chant or cheer to the Athlete(s)
 4. applaud to the Athlete(s) good performance (e.g., at a goal scene)

so that I can have an immersive user experience as if I am at the stadium/arena.

- interact with other Audience Members
 1. cheer together and share the excitement with other Audience Members and monitor how other Audience Members see me
 2. view the performance anywhere with multiple devices-e.g., TV, Screen, tablet, smartphone, HMD as that I can change location and switch devices accordingly

so that I can share exciting experiences with other Audience Members.

3.1.2.2.2. Persona #2: Athlete(s)

As an Athlete(s), I want to;

- interact with the Audience Members
 1. see, hear, and feel the Audience Members' cheer
 2. request for chant, cheer

so that I can hear Audience Members cheering and booing me to feel the Audience Members' enthusiasm.

3.1.2.2.3. Persona #3: System Operator

As a System Operator, I want to;

- monitor the state of the Athlete(s)
 1. location and direction regarding camera/mic position to select and create effects—e.g., ROI, lightning, etc.
 2. video/audio quality provided toward the Athlete(s) to adjust and adapt operation mode to give the best performance to Audience Members within the range of affordable costs.
- monitor the state of Audience Members
 1. engagement state of the Audience Members to select and provide toward the Athlete(s) the feedback of excitement at the Audience Members
 2. video/audio/data quality provided to Audience to adapt operation mode
 3. video/audio/data quality provided toward the Athlete(s) to select appropriate feedback toward the Athletes(s)
 4. behavior of Audience Members to exclude them if they do not have an appropriate behavior in their interaction

- select the Athlete' (s) highlight scene to be used
- select the Audience Members' feedback to be used
- create a virtual space where the Athlete(s) and Audience Members coexist and interact with overlaying natural and artificial images

so that I can give an immersive experience to both athletes and Audience Members.

3.1.2.2.4. Persona #4: Organizer

As an Organizer, I want to;

- collect behavior of the Athlete(s) during the sports event
- collect the behavior of the Audience Member(s) during the event
 1. interaction toward the Athlete(s)
 2. interaction toward the other Audience Members
 3. other interaction over the network
- analyze the collected data

so that I can enhance and reflect on subsequent events.

3.1.2.3. Service Gap/Requirements

- Immersive virtual space creation: Bandwidth/latency is not enough to collect images, sound, and sensor data from Athlete(s) and Audience Members. Computational power is limited to create an immersive virtual environment in a real-time fashion
- Immersive virtual space distribution: Bandwidth/latency is not enough to distribute personalized virtual space data toward large-scale distributed Audience Members. Also, the means to synchronize images, sound, and sensor data from Athlete(s) and Audience Members within the required latency are lacking
- Data Analysis platform: There are no sufficient means to collect data in a consolidated manner that includes Athlete(s)-to-Audience Member(s), Audience Member(s)-to-Athlete(s), Audience Member -to-Audience Member. In addition, data transactions in the cloud (virtual space) and data transactions made in P2P both need to be considered

Service requirements can be summarized as follows;

- number of Audience Members: ~1,000,000,000 [FIFA, 2018].
- raw data rate at Athlete(s): 90 ~ 230 Gbps
 - note: the data rate depends on the emulated distance from the eye to the object (1m@120fps: 230 Gbps, 3m@90fps: 90 Gbps)
- latency
 - interactive/synchronous components: ~10 msec
 - synchronous Sound: ~20 msec
 - non-verbal communication (e.g., waving hands): ~100 msec
 - verbal Communication: ~300 msec
- End-to-end QoS across wired/wireless connectivity

3.1.3. Cloud Gaming

3.1.3.1. Description

In the video game industry, cloud gaming is a game-provision model in which a network and server generate game images and distribute them to user terminals. Cloud gaming has the following advantages: i) the users can play high-spec games on inexpensive terminals, ii) distribution costs including game software updates can be reduced, and iii) it is easy to manage the game data of multiple terminals belonging to a user. However, cloud gaming incurs additional delays (denoted as 1 to 4) in Figure 4 compared to the terminal-processing game model that generates game video on user equipment such as a game console, PC, or smartphone. For this reason, it is currently almost impossible to play all games on a cloud gaming system with the same quality as consoles.

The IOWN Global Forum's proposed solution will significantly improve the performance of cloud gaming and dramatically change the user experience and delivery model of video gaming. Game Users will be able to play all games immediately without an expensive console or PC. Furthermore, eSports Organizers will be able to easily hold fair eSports events at multiple locations.

The following Personas appear in this use case as illustrated in Figure 5:

- Game User: Person who plays video games
- Game Platformer: Person or group who provides game platforms for users to play games
- Game Content Provider: Person or group who provides game content with game platforms
- eSports Organizer: Person or group who holds eSports events with game platforms and contents

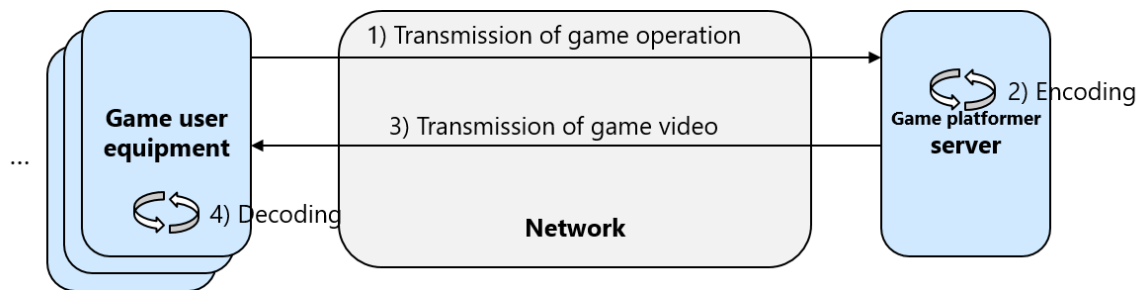


Figure 4 Additional Delay in Cloud Gaming

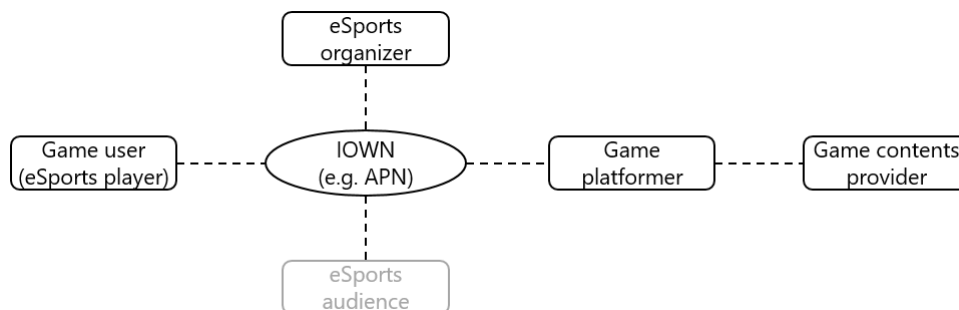


Figure 5 Overview of Cloud Gaming

3.1.3.2. Key Feature Set

3.1.3.2.1. Persona #1: Game User

As a Game User, I want to;

- play all low latency games on inexpensive terminals or without terminals
 1. play my favorite game content without having to buy a compatible console first
 2. play various games without having consoles from multiple manufacturers and multiple generations at home
- start the game quickly without waiting for the download time of the game content
- use the game data of my multiple terminals easily

3.1.3.2.2. Persona #2: Game Platformer

As a Game Platformer, I want to;

- orchestrate network functions and services to provide the best performance/lowest latency to Game User/eSports Players
- gain and keep game users on my platform as game hardware technology evolves
- reduce the development cost of consoles
- gain new contents provider

3.1.3.2.3. Persona #3: Game Contents Provider

As a Game Contents provider, I want to;

- update my game contents frequently and quickly to get users to continue playing the game contents
- provide my game content to many users

3.1.3.2.4. Persona #4: eSports Organizer

As an eSports Organizer, I want to;

- hold eSports fair events easily
 1. reduce the amount of game equipment needed at the venue when hosting eSports
 2. provide eSports players with a fair gaming environment
- broadcast eSports competitions easily without having to capture video at the venue

3.1.3.3. Service Gap/Requirements

As shown in Table 1, some games require a delay of 10 ms or less from user operation to screen display (including delays 1 to 4) in Figure 4. Low-latency and low-jitter network transfer and server processing technology are required to enable access to all game content in cloud gaming. Synchronization of games between multi-users is also required within the required low latency to ensure acceptable performance.

Table 1: Guidelines for Acceptable Delays by Game Category [Nakajima, 2018]

Game category	Delay
FPS (FP/First-Person shooter, PVP/Player versus Player) Official game	5–15 ms
FPS (PVP general)	10–30 ms
Battle fight (1-to-1)	5–30 ms
Racing game (PvP)	10–50 ms
Super Smash Bros. PvP	10–50 ms
2D side view jump game	10–50 ms
VR space sharing	10–100 ms
FPS (PvE/Player versus Environment)	30–100 ms
RTS (Real-time Strategy) / MOBA (Multiplayer Online Battle Arena)	20–100 ms
2D looking down action	50–100 ms
TPS (Third Person Shooter)	50–100 ms
Smartphone real-time action	50–200 ms
Voice chat	50–200 ms
Massively Multiplayer Online	100–300 ms
MMORPG (Massively Multiplayer Online Role-Playing Game)	100–500 ms
Smartphone turn-based games	200–1000 ms

In the 2020s, it is expected that game consoles with 8K image quality and 120-fps performance will become common. Therefore, to provide a cloud game with the same quality as a game console, IOWN technology, which enables high-quality and low-latency games, is required.

Service requirements can be summarized as follows:

- Number of the game users: ~ 100,000
- Data rate:
 - raw data rate at the game user: 72 ~ 144 Gbps (8K, 120-fps)
 - compressed data rate at the game user: 200 ~ 400 Mbps (8K, 120fps)

note: There is a trade-off between latency and data rate, so it is worth considering an appropriate solution using IOWN technology in the IOWN Global Forum.
- latency: 10 ~ 600 ms
- game synchronization within the required latency

3.1.4. On-the-Go Entertainment

3.1.4.1. Description

By combining fully autonomous driving technology and innovative communication and processing technology, IOWN Global Forum will enable an unprecedented in-vehicle entertainment experience. While traveling to their destination, users will enjoy immersive and interactive entertainment as if the vehicle was their private theater. The arrival of mainstream autonomous vehicles represents an extremely rare event in which users will see an increase in their “disposable time.” Content providers will vigorously compete for this time.

While various types of entertainment, including Interactive Live Entertainment or Cloud Gaming, are envisioned, we will use Interactive Live Sports as described in Section 3.1.1 as an example use case that passengers of next-generation vehicles will enjoy.

3.1.4.2. Key Feature Set

3.1.4.2.1. Persona #1: Audience Member (i.e., Passenger)

As a Audience Member, I want to:

- interact with the Athlete(s)
 1. view the Athlete(s) with high fidelity 360-degree free perspective video and audio
 2. playback a highlight (e.g., a goal scene) of the Athletes' performance and Athletes' view
 3. send chant or cheer to the Athlete(s)
 4. applaud to the Athlete(s) good performance (e.g., at a goal scene)

so that I can have an immersive user experience as if I am at the stadium/arena.

- interact with other Audience Members (people who are participating in a live sports event from home)
 1. cheer together and share the excitement with other Audience Members and monitor how the other Audience Members view me
 2. view the performance with multiple devices-e.g., in-vehicle display, tablet, smartphone, HMD and switch devices accordingly

so that I can share exciting experiences with other Audience Members.

3.1.4.2.2. Persona #2: Athlete(s)

As an Athlete(s), I want to:

- Interact with the Audience Member
 1. see, hear, and feel the Audience Members' cheer
 2. request for chant, cheer

so that I can hear Audience Members' cheering and booing me to feel Audience Members' enthusiasm.

3.1.4.2.3. Persona #3: System Operator

As a System Operator, I want to;

- monitor the state of the Athlete(s)
 1. location and direction regarding camera/mic position to select and create effects—e.g., ROI, lightning, etc.
 2. video/Audio quality provided toward the Athlete(s) to adjust and adapt operation mode to provide the best performance to Audience Members within the range of affordable costs.
- monitor the state of Audience Members
 1. engagement state of the Audience Members to select and provide toward the Athlete(s) the feedback of excitement at the Audience Members

2. video/audio/data quality provided to Audience Members to adapt operation mode
 3. video/audio/data quality provided toward the Athlete(s) to select appropriate feedback toward the Athletes(s)
 4. behavior of Audience Members to exclude them if they do not have an appropriate behavior in their interaction
- select the Athlete' (s) highlight scene to be used
 - select the Audience Members' feedback to be used
 - create a virtual space where the Athlete(s) and Audience Members coexist and interact with overlaying natural and artificial images
- so that I can give an immersive experience to both Athletes and Audience Members.

3.1.4.2.4. Persona #4: Organizer

As an Organizer, I want to;

- collect behavior of the Athlete(s) during the sports event
- collect the behavior of the Audience Member(s) during the event
 1. interaction toward the Athlete(s)
 2. interaction toward the other Audience Members
 3. other interaction over the network
- analyze the collected data

so that I can enhance and reflect on subsequent events.

3.1.4.3. Service Gap/Requirements

- Immersive virtual space creation: Bandwidth/latency is not enough to collect images, sound, and sensor data from Athlete(s) and Audience Members. Computational power is limited to create an immersive virtual environment in a real-time fashion
- Immersive virtual space distribution: Bandwidth/latency is not enough to distribute personalized virtual space data toward large-scale distributed Audience Members. Also, means to synchronize images, sound, and sensor data from Athlete(s) and Audience Members within the required latency lacking
- Data Analysis platform: No sufficient means to collect data in a consolidated manner that including Athlete(s) to Audience Members, Audience Members to Athlete(s), Audience Members to Audience Members. Data transactions in the cloud (virtual space) and data transactions made in P2P both need to be scoped
- Service migration: There are no sufficient means to dynamically migrate communication and computational resources that handle massive video and audio streams within required latency.

3.2. Remote Operation

The IOWN Global Forum will expand the scope of various remote operations. In this section, we describe how the IOWN Global Forum intends to change remote learning.

3.2.1. Professional Learning

3.2.1.1. Description

As Covid-19 spreads worldwide, almost all cities or states/provinces have mandated a shelter-in-place or a complete lockdown stage at some point during this pandemic. While everyday stay-at-home life has not been entirely disrupted thanks to the current technologies in communications, there are still some restrictions.

For instance, if someone needs to conduct remote learning involving a hands-on training session like disassembling a car engine, it is impossible without invoking Augmented Reality and Virtual Reality technologies. To fully realize an immersive remote experience, all five human senses need to be digitized and the resulting data transferred across networks in near real-time. Streaming holographic videos over a network requires high data bandwidth and low latency to accommodate a large amount of hologram data and increased fidelity.

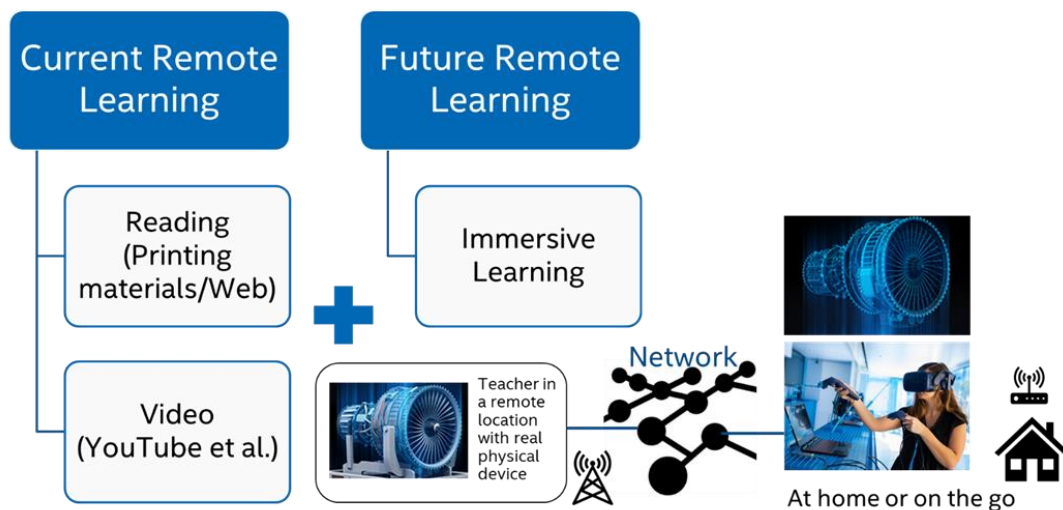


Figure 6 XR Application for Remote Learning

Remote expert support is another use case when a shelter-in-place order or lockdown stage is in force. Issues on-site such as plumbing problems, heater/air condition breakdowns, computer problems, or more severe issues need to be remedied with professional assistance. However, the travel between the expert's location and the customer site is sometimes not possible due to pandemic lockdown regulations.

Armed with Augmented Reality and Virtual Reality technologies, the remote expert can have an immersive surrounding experience, seeing and comprehending exactly what the customer sees on site.

This allows the expert to better understand the overall context and provide specific troubleshooting and repair instructions. The real-time haptic feedback enables the customer who may have minimum skill and no prior experience to execute troubleshooting or repair simultaneously with closely guided and real-time assistance, as illustrated in Figure 6.

3.2.1.2. Key Feature Set

3.2.1.2.1. Persona #1: An Educator (for Remote Learning)

As an Educator, I want to;

- able to give a remote hand-on teaching session via a virtual reality system
- deliver teaching sessions via a wireless or wired network
- students to follow me INSTANTLY to disassemble/assemble complex engines using hologram model so that my student(s) can learn effectively as if they were in the same physical classroom.

3.2.1.2.2. Persona #2: A Consumer (for Remote Support)

As a Consumer without any prior knowledge/experience in plumbing, I want to;

- fix a leak in the kitchen with remote support from a plumber
- get support via mobile network
- take a high-definition photo/image of the problem area to generate a 3-D hologram image
- able to stream high-definition photo/video around the problem area to the plumber
- mimic in real-time how plumber interacts with digital model simultaneously

so that I can fix the plumbing problem without waiting for the plumber to come, which may be restricted due to various reasons (lockdown, weather/road conditions, et al.).

3.2.1.3. Service Gap/Requirements

Currently, remote learning involves students learning through the reading of text materials or through watching videos on YouTube or other video platforms. These methods are acceptable to gain general knowledge. However, if learning involves very complicated objects and requires hands-on experience, such as assembling a turbo engine, watching video and reading are ineffective as they provide only two-dimensional aspects of the object. This is where immersive learning utilizing AR/VR comes into play. With AR/VR, students at home or another remote location can follow the instructions of a teacher working with a real physical device since they are working with a 3-D image of the exact model that the teacher is using.

Today's technologies cannot deliver this kind of learning because of extremely high bandwidth requirements. For example, without any compression, a raw hologram with colors, full parallax, and 30 fps will need a 4.32 Tbps data rate. In addition to bandwidth requirement, haptic response time needs to be in the order of sub ms range [M. Giordani, 2020]. 5G wireless networks typically target a 1 Gbps data rate and 1 ms latency. Many factors affect whether these 5G performance goals can be achieved. Issues including the amount of 5G spectrum allocated, cell traffic level, backhaul capacity, and others may become a roadblock to reach 1 Gbps for the average user. Some of the factors impacting network latency include 5G numerology (slot duration), edger server location, network configuration (Non-standalone vs. standalone), backhaul configuration, and traffic loading. Currently, the E2E network latency in a general commercial 5G network can achieve ≥ 8 ms latency at best. Network slicing can allow some users to achieve better performance, but latency with 1 ms is yet to be achieved in a commercial 5G network. In summary, the current 5G network work cannot meet stringent performance requirements of 4.32 Tbps and less than 1 ms latency.

AR/VR devices based on the stereoscopic principle utilize only human's binocular depth perception to create 3D images. In the future, glasses-free, truly holographic 3D Displays are expected to provide all depth cues and eliminate eye fatigue or visual discomfort.

Service requirements can be summarized as follows:

- cameras in a mobile device can take 8k HD photo/video
- 12 tiles for VR/AR
- glasses-free truly holographic 3D displays
- high data rate (4.32 Tbps)
 - a raw hologram, without any compression, with colors, full parallax, and 30 fps, would require 4.32 Tbps
- ultra-low network latency (haptic response time sub ms to 5.5 ms)
 - the latency requirement for Holographic Telepresence will be in the range of sub-ms, and thousands of synchronized view angles will be necessary
- continuous connection reliability (99.9999%)
 - in some remote learning scenarios, where a fast haptic response is a critical element of the learning, isochronous operation adds tight constraints on jitter and the communication service reliability as high as 99.9999%

3.3. Navigation

The IOWN Global Forum aims to change how people navigate the physical world. In this section, a new use case on navigation using XR technology is described.

3.3.1. Ultra XR Navigation

3.3.1.1. Description

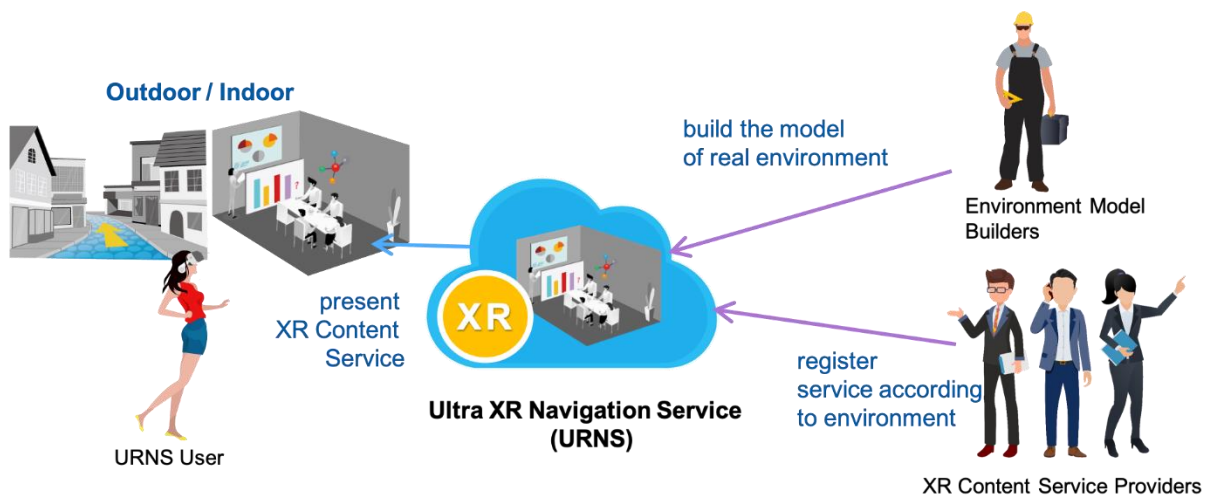


Figure 7 Overview of Ultra XR Navigation Services

The IOWN Global Forum will revolutionize how people experience the world and how the services/applications are appropriately provided to users through the Ultra XR Navigation Service platform, as illustrated in Figure 7. The benefit of XR different from other technologies is to combine the information or the simulation with the individual's surrounding environment making data real and vivid. The world changes with the passage of time, and we make various decisions by considering the past, current, and future. Therefore, The IOWN Global Forum, with its AI Photonic Network, will fulfill the idea in Time-travel XR Navigation Service platform.

For instance, there are the following cases:

- at the restaurants or physical retail shops, you could feel the texture, size, weight, smell, and various additional specifications like a finished product by XR device, as if it were made already
- you can see the past and future of the object that you watch through the XR device
- you can get the experience of traveling while staying at home when your friends go to a tourist site with an XR device that interacts with you

The following Personas appear in this use case:

- User: People who use XR devices experience the past, current, and future world
- Environment Model Builder: Person or group models the real-world environment to digital data, helping the platform recognize the user's environment
- XR Content Service Provider: Person or group designs the XR Content Service according to a specific environment
- Platform Provider: A platform that provides XR content services according to the user's location

3.3.1.2. Key Feature Set

3.3.1.2.1. Persona #1: User

As a User, I want to;

- interact with the platform
 1. see a well-designed XR Content (text, picture, video, 3D Model, etc.) showing up when I walk into a registered location
 2. see the past and future of XR Content
 3. feel XR Content with my body and give feedback to the platform
 4. get a recommendation and advice yielding the best result
 5. make another User see what I see and manipulate my AR Content

3.3.1.2.2. Persona #2: Environment Model Builder

As an Environment Model Builder, I want to;

- interact with the platform
 1. create an object with a huge amount of data, quickly and precisely

2. record all the digital features (coordinates, magnet, 3D point cloud, etc.) of a specific environment/location precisely
3. register a recorded environment/location

3.3.1.2.3. Persona #3: XR Content Service Provider

As an XR Content Service Provider, I want to;

- interact with the platform
 1. design and register my XR Content Service in a specific environment to express my world precisely
 2. register my XR Content Service on a specific environment/location so that the User could be well-served when they walk in this environment
 3. make the platform know how to render my content and connect relevant services such as other XR Content Service Providers to expand my world

3.3.1.2.4. Persona #4: Platform Provider

As Platform Provider, I want to;

- interact with the User
 1. recognize where the User is precisely.
 2. show the User XR content according to the User's vision.
 3. recognize User's feedback actions such as pointing by finger, nodding, grabbing, walking, and so on

3.3.1.3. Service Gap/Requirements

To create an XR world that combines virtual and physical aspects, it is necessary to accurately capture the state of the natural world and objects, convert them into data, and link them with the virtual space in real-time.

For service users to experience the XR world without feeling uncomfortable

- A precise space locating technology: With more and more environments/locations modeled in the cloud, locating the User's position could be complicated. We need to get an accurate picture of the real world. It is necessary to specify exact locations, both outdoors and indoors, and in some cases to accurately capture the latitude, longitude, and height of objects at the inch level.

Real-time massive data transmission: Dozens to hundreds of megabytes of data per object, such as 3D CAD data, must be instantly downloaded and displayed on a user's device. The amount of data becomes even larger as the object becomes more precise.

From the perspective of the service provider:

- An instant cloud rendering technology: According to the User's vision input, a cloud rendering technology should render XR Content then send it back to the User. The bandwidth/latency and the computing time would be an obstacle to a good user experience
- Edge AI technology: To recognize the User's position and the User's action, edge AI technology is needed to shorten the response time of XR content rendering result and the feedback of the User's action

3.4. Human Augmentation

The IOWN Global Forum aims to create new technology that would expand the capabilities of a human being. In this section, we describe new use cases on mind-to-mind communication and Another Me application.

3.4.1 Mind-to-Mind Communications

3.4.1.1. Description

Human civilization continues to evolve through communication and interactions with other cultures. Conflicts often arise from misunderstandings in communication, even if the participants speak the same language. While the explicit meaning of words is understood, the nuance behind unspoken background thoughts is often not fully comprehended by the respective parties. The result is that one or both parties often do not truly comprehend the other person's point of view. To overcome this challenge, the IOWN Global Forum proposes that mind-to-mind communication technology will realize a new form of communication that overcomes differences in language, culture, and individual characteristics to enable direct understanding of each other's perceptions and emotions.

AI technology has emerged that is capable of overcoming gaps in vocabulary in real-time, thus providing near-simultaneous interpretations for two parties that speak different languages. However, translating and presenting actual emotions or implicit meanings that play a crucial role in decision-making are yet to be achieved.

Mind-to-Mind communications will bring about a new era of communications that will overcome differences in language, culture, experience, values, and sensibilities to provide a real and direct understanding of how other people perceive and feel things in their minds through the transmission of expressed words and expressions.

This new approach seeks to reduce and eliminate communication discrepancies, increase psychological assurance, and promote mutual understanding in our fragmented world to create an inclusive and harmonized approach to problems where people with diverse characteristics can work together, stimulate each other, and grow together.

The ultimate goal of this use case is to realize mind-to-mind communications as described in Figure 8.

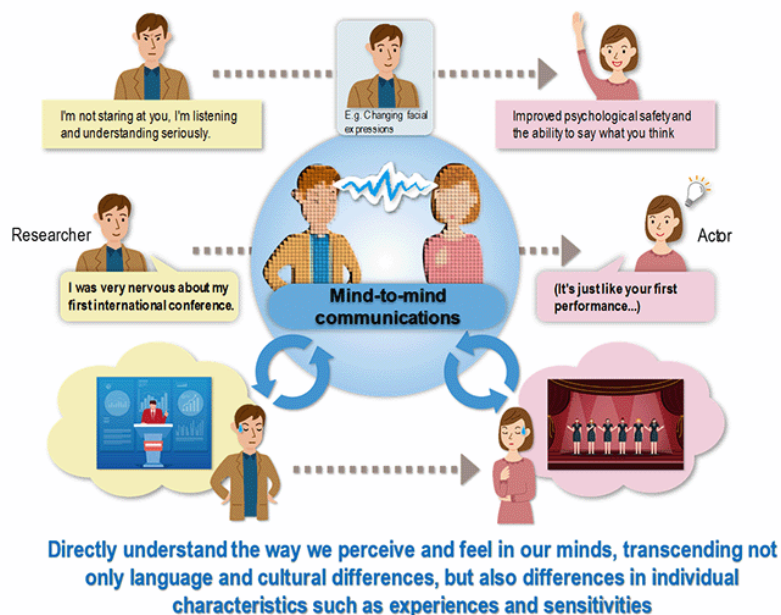


Figure 8 Mind-to-Mind Communications

3.4.1.2. Key Features

3.4.1.2.1 Persona #1: An Individual who wants to communicate with others

As an Individual, I want to;

- smoothly communicate with others who originate from other countries, background, e.g., education, professions, gender
- easily understand what the others mean, translated into comprehensible language, expression with no lag

3.4.1.2.2 Persona #2: Service Provider

As a Service Provider, I want to;

- calculate the psychological state of individuals involved in mind-to-mind communication. This will be based on an individual's collected and accumulated information, i.e., context, including backgrounds, behavioral logs, situations, and cultural values
- analyze psychological state from dialog text, voice, facial expression, and any other physiological signs on a real-time basis through wearable devices. On the receiver's end, this conveyed information must be converted appropriately in terms of the receiver's context and projected graphically in a wearable device's display in means of AR/VR

3.4.1.3 Service Gap/Requirements

- in the early stages of development, the differences in communication characteristics such as superficial attitudes and expressions must be transcended to achieve smooth, discrepancy-free face-to-face communications in lag, which does not interfere with smooth human communications/dialogs. To achieve this, communication and psychological characteristics must be modeled and classified in a digital format. Also, comfortable wearable devices that do not distract from an ordinary conversation need to be developed
- later, the conversations will be assisted with how the talker perceives and feel things viscerally through messages transcending differences in experiences and sensibilities
- ultimately, communications that enable receivers to directly understand how senders perceive and feel things in their minds and thus absorbs the differences in experiences and sensibilities will have to be realized
- these defining concepts and technologies can be used as a reference for building human digital twins. In other words, the reference model of the digitalized human data or 'human digital twin' will be needed

3.4.2. Another Me

3.4.2.1. Description

Many of us are familiar with technologies we use to represent us or act on our behalf. Some include a simple answering machine or voicemail box, a health profile, or perhaps an avatar in a game. What if we can combine these use cases into a single model? The result may be a digital representation that acts on our behalf in certain aspects in certain

situations. This digital avatar would be capable of recording information and even making decisions on our behalf, then instantly make this knowledge available to us or even other avatars operating in other circumstances.

Such a digital instance of ourselves would have to be controlled by us exclusively. We would be able to set the parameters by which it engages with others and only allow it to operate in those situations we approve. Individuals could also make use of the “experience” the digital instance would make in its interactions.

Such an alter ego or entity in the digital twin space, Another Me, can expand our lives and opportunities. It would also be ideal if those entities also grow with us, as we do in real life.

The human digital twin can potentially compensate for the loss of various opportunities in life and brings us more enriched life, such as balancing work with childcare and nursing care, which will allow us to participate and contribute to society.

The ultimate goal of this use case is Another Me, as summarized in Figure 9.

By 2035, Another Me, an alter ego that coexists and grows in digital twin space, will address these issues. All the experience and knowledge performed both in real life and digital twin spaces will be shared between Another Me and one’s real self, thus creating more than double the opportunities to play multiple roles simultaneously. Another Me aims to improve emotional well-being, health, and life satisfaction by enabling users to perceive many opportunities in life, such as balancing work and family and participating in many communities simultaneously.

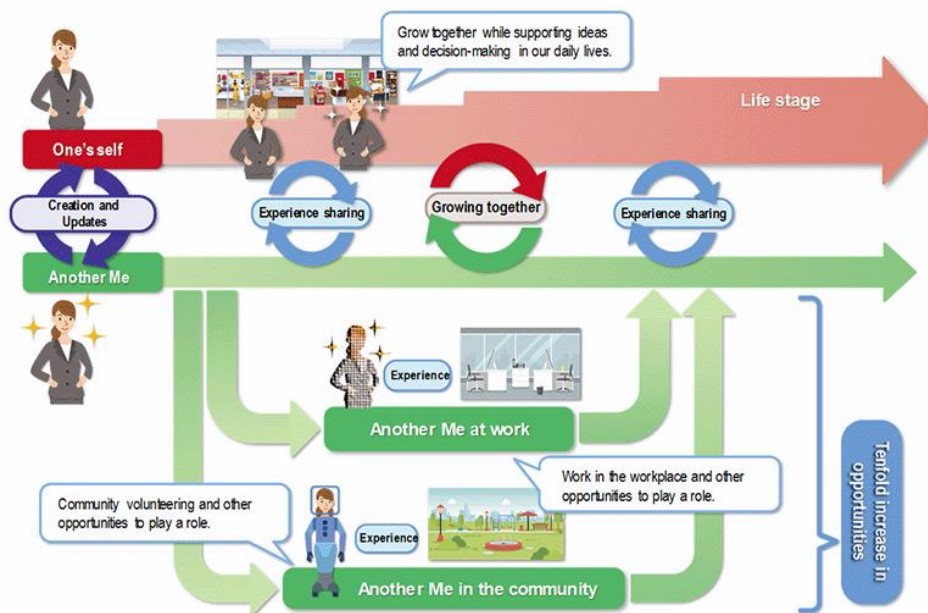


Figure 9 Another Me

3.4.2.2. Key Feature

3.4.2.2.1. Persona #1: Another Me User

As an Another Me User, I want to;

- take a leave from work and let Another Me do the tasks instead, e.g., not only email replies and meeting arrangements but also meeting attendance, discussion, writing various documents. This Another Me is an avatar

of me in digital twin space and will behave just like myself. Another Me may be confined in a digital twin world and reach the real world through robotics technologies

3.4.1.2.2 Persona #2: Another Me Service Provider

As an Another Me Service Provider, I want to

- provide storage and computational power to maintain more than one Another Me entity in digital space and provide means to communicate and share the experience of one's real self
- make all the thoughts, experiences, and memories of the entities (amongst digital twin and real world) be shared instantaneously

3.4.2.3. Service Gap/Requirements

- to accurately reproduce a human being in digital space, the required computational power is said to be in the order of some hundred Petaflops. This computational power can only be reached in 2020 by a super-computer. For multiple instances of humans to interact in the digital space, the figure is not achievable by today's technology.
- all transactions between a person and computed result in digital space must be made instantaneously to facilitate smooth communication. (The tolerated lags for auditory, visual, and tactile sensing are reported to be 100, 10, and 1 msec, respectively. [International Telecommunication Union, 2020]) Digital twins must also be able to sense everything that a person experiences in real life and provide concise feedback to the real person on what it experiences in the digital world
- it is not yet realistic to collect all comprehensive personal data, so the technology to reconstruct a person's character from a selected and limited data must be established. This information must also be stored securely and retrieved appropriately
- defining concepts and technologies that can be used as a reference for building human digital twins. In other words, the reference model of what the digitalized human data or 'human digital twin' is will be needed
- Human Digital Twin (HDT) controlled robotics would increase the networking and real-time demands of what is discussed today as "cloud robotics," where the concept of an "extended brain" exists to offload heavy computation to data center servers and to use a "shared brain" to build a common database to collect and organize information about the world and learned skills/behaviors. HDT controlled robotics would have to maintain the differences of the individuals

4. Requirements

As described in the previous section, AIC Use Cases involve manipulating the human senses to virtually recreate an experience that is physically occurring at a distant location. The most critical requirement that arises from the set of use cases is the ability to deceive human senses by transferring the experience through the network without human recognition. This requirement is further described as the **Data Velocity** aspect below. The full set of key requirements can be depicted as follows.

Common workflows for the AIC Use Cases are shown in Figure 10.

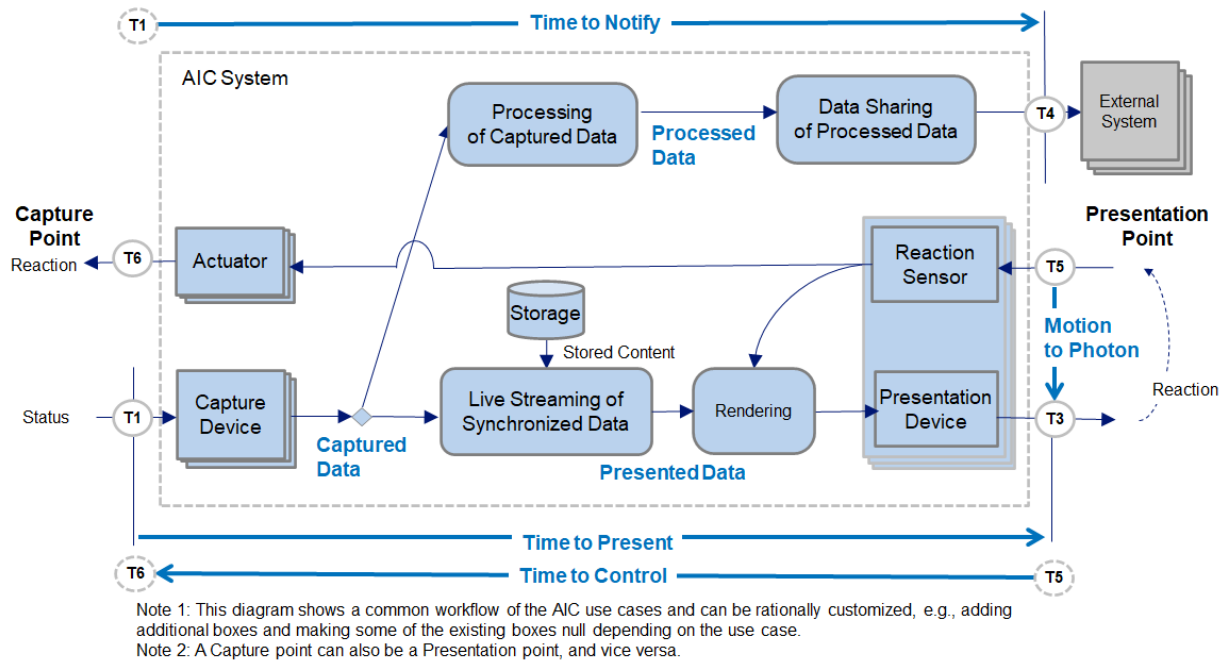


Figure 10 Common Workflows and Key Requirements for AIC Use Cases

Key requirements can be expressed along with the following workflows;

- **Data Sharing** (T1 to T4): “Processed Data” are made available to “External Systems” through “Data Sharing of Processed Data”. The end-to-end delay for this flow is named “Time to Notify (TTN)”.
- **Remote Live Monitoring** (T1 to T3): “Captured Data” are transferred to “Presentation Devices” in remote sites for remote live monitoring via “Live Streaming of Synchronized Data” and/or “Rendering”, which are used for the creation of enriched contents from multiple streams of “Captured Data”. The end-to-end delay for this flow is named “Time to Present (TTP)”.
- **Motion to Photon** (T5 to T3): The data captured by “Reaction Sensors” are reflected the presented view on the person’s “Presentation Device”, which provides, for example, a personalized view of a free viewpoint video. The end-to-end delay for this flow is named “Motion to Photon (MTP)”.
- **Remote Control** (T5 to T6): The data captured by “Reaction Sensors” are directly dispatched to “Actuators” at remote sites, which enables, for example, remote motion control of specific machines. The end-to-end delay for this flow is named “Time to Control (TTC)”.
- Given the above workflows, the following aspects will be critical key requirements of the AIC Use Cases;

- **Data Volume:** Volumetric capturing will be the new norm in the AIC Use Cases, which would produce a **few Tbps** of “Captured Data “if uncompressed. Because the UCs also require a minimal delay, deep compression cannot be expected. Even when the data are compressed, the rate would at least be in the order of hundreds of Gbps. It is expected that the use of next-generation display technology such as Holographic display would require delivery and computation of several hundred Gbps to a few Tbps of “Presented Data “.
- **Data Velocity:** As described below, some AIC Use Cases require less than **10 ms** “MTP, which will be the most critical requirement. Using 1ms for capturing (posture-eye motion) and 2 ms for displaying leaves only 6ms for networking and computing.
- **Scalability and Elasticity:** Some AIC Use Cases, such as Live Entertainment and Live Sports, will enable a vast number of users to share the same remote experience via the network. The network needs to support scalability and elasticity to support varying user demand, for example, a **sporadic surge in communication** at a goal scene of a football match.
- **Other Aspects:** Wireless connectivity at the user device is a common requirement for most AIC Use Cases. More critical AIC Use Cases, such as Professional Learning have more stringent requirements such as **1 ms jitter** and **99.9999% reliability**.

The details on the key requirements for each use case are described in the following subsections.

4.1. Entertainment

4.1.1. Interactive Live Music

In this use case, the Artist and many Audience Members gather and interact with each other in one virtual space. Each Audience Member can see the virtual space according to their posture-eye movement. Therefore, the response time of these interactions (MTP and TTP) by high bitrate video stream is the crucial requirement to realize this use case

4.1.1.1. Key Requirements

- **Data Volume:**
 - video stream (uncompressed) from Capturing Device: 14-230 Gbps per object (total ~ 2 Tbps)
 - ◇ number of objects: ~8
 - video stream to Presentation Device: 48-200 Gbps
- **Data Velocity:**
 - MTP: 10 ms
 - TTP: 70 ms
- **Scalability:**
 - automatic scaling of network and computing resources is required according to the number of Audience Members joined

4.1.1.2. Assumptions

- **Capacity-Geographic:**
 - total audience of up to 100,000
 - latency requirements applicable to Audience Members up to 1,000 km distance

4.1.2. Interactive Live Sports

Similar to the Interactive Live Music as described in Section 4.1.1, motion-to-photon latency (MTP) is crucial, as well as the latency from capturing a live sports event to present Audience Member's display (TTN).

4.1.2.1. Key Requirements

- **Data Volume:**
 - video stream (uncompressed) from Capturing Device: 14-230 Gbps per object (total ~ 2 Tbps)
 - ◇ number of objects: ~8
 - video stream to Presentation Device: 48-200 Gbps
- **Data Velocity:**
 - MTP: 10 ms
 - TTP: 70 ms
- **Scalability:**
 - automatic scaling of network and computing resources is required according to the number of Audience Members joined
 - the data rate of other Audience Members' images may become higher after a goal scene to share the excitement more intimately

4.1.2.2. Assumptions

- **Capacity-Geographic:**
 - total Audience of up to 100,000
 - latency requirements applicable to Audience Members up to 1,000 km distance

4.1.3. Cloud Gaming

In order to provide Game Users with a game service as if they were playing it on the game console, the motion-to-photon latency (MTP) that indicates the time for Game User's posture-eye movement or game controller's event to be fully reflected on Game User's display screen is the most important requirement.

4.1.3.1. Key Requirements

- **Data Volume:**
 - video stream to Presentation Device: 72~144 Gbps
- **Data Velocity:**
 - MTP: 10~600 ms
- **Scalability:**
 - automatic scaling of network and computing resources is required according to the number of users joined

4.1.3.2. Assumptions

- **Capacity-Geographic:**
 - the total users up to 100,000
 - latency requirements applicable to users up to 1,000 km distance

4.1.4. On-the-Go Entertainment

This is a similar use case for Interactive Live Sports as described in Section 4.1.2. However, in this use case, Audience Members here are watching a live sports event on vehicles. Therefore, high-speed wireless connectivity, automatic and dynamic switching of computing resources on the local edge, and switching a network path from the cloud edge to the center cloud with a high bitrate video stream is crucial.

4.1.4.1. Key Requirements

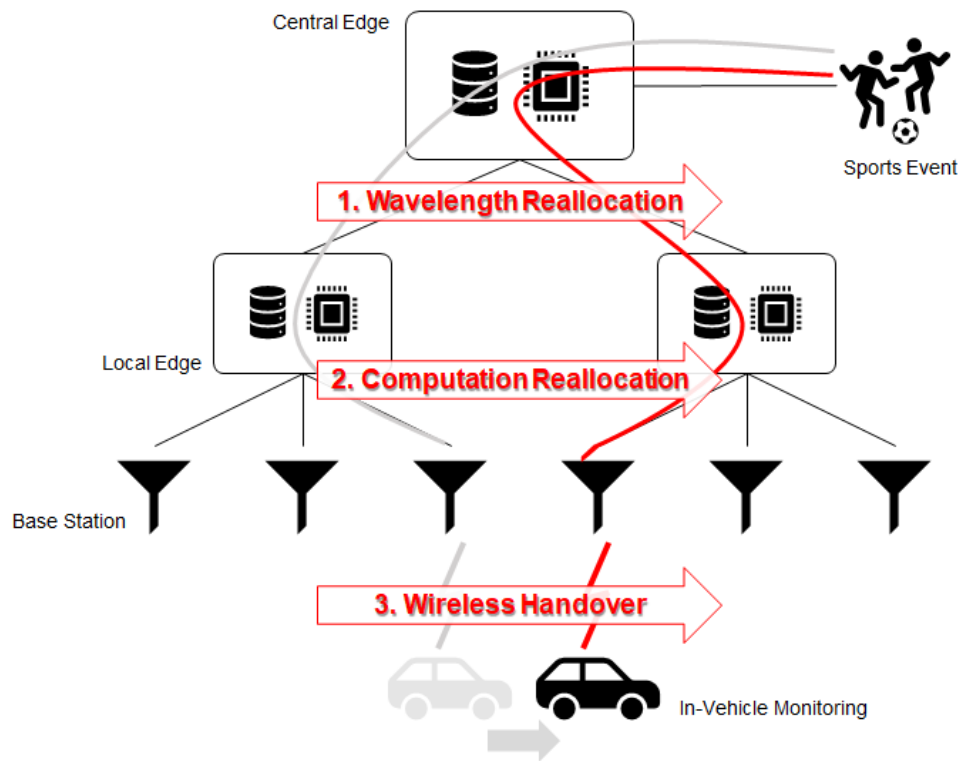


Figure 11 Key Requirement unique for On-the-Go Live Entertainment

- **Data Volume:**
 - same as that of 4.1.2. Interactive Live Sports 4.1.2.1. Key Requirements
- **Data Velocity:**
 - same as that of 4.1.2. Interactive Live Sports 4.1.2.1. Key Requirements
- **Scalability:**
 - same as that of 4.1.2. Interactive Live Sports 4.1.2.1. Key Requirements
- **Other Aspect**
 - high-speed wireless connectivity (up to 200 Gbps per Audience/Passenger) is necessary. Also, the ability to dynamically transfer communication and computational resources to track the moving vehicle is a need

4.1.4.2. Assumptions

- **Capacity-Geographic:**
 - total Audience Members of up to 100,000
 - latency requirements applicable to Audience Members up to 1,000 km distance

- Mobility Aspect
 - Vehicle Speed: 60 km/h = approx. 16.7 m/s
 - Vehicle Traffic: 100,000 vehicles /12h = approx. 2 vehicles /s
 - Vehicle Density
 - ◇ 200 vehicles / 10 km Service Area (10000m / 16.7m x 2 vehicles), 12 vehicles / cell (cell size = 100m), assuming 1-dimension cell

4.2. Remote Operation

4.2.1. Professional Learning

4.2.1.1. Key Requirements

- **Data Volume:**
 - Captured Data / Presented Data:
 - ◇ 8K*8K in Visual Field: 2.35 Gbps per instructor or student
 - ◇ Hologram: 100 Gbps to 4.32 Tbps per instructor or student
 - note: While the number expresses the data volume with uncompressed data size, it is reasonably assumed that some implementations would most likely compress data. However, we should choose a compression method that does not result in a severe increase in latency.
- **Data Velocity:**
 - TTC: 10 ms to 20 ms (without haptics)
 - TTC: sub ms to 2 ms
 - TTC + TTP: 5.5 ms (for haptic feedback)
- **Scalability:**
 - 1-100 students within a cell
- **Other Aspects:**
 - Network Jitter / Reliability: 1 ms jitter, 99.9999% reliability

4.2.1.2. Assumptions

- **Common:**
 - high reliability and QoS (Ultra-low latency and jitter) ensure synchronized rendering of audio, video, and haptic response
 - Over the Air (OTA) access network can be either a cellular network or WiFi. A cellular network is assumed as it has less dependence on location

- the uplink requirement is likely to be for a single user, while downlink's can be for one or more users
- interactive holographic/AR/VR applications are used in a non-dedicated network, i.e., sharing network resources with other users and applications. Not all network resources are exclusively allocated to holographic/AR/VR applications
- holographic use cases: remote expert support, remote learning, remote healthcare, remote game
- **Captured Data / Presented Data:**
 - a raw hologram, without any compression, with colors, full parallax

4.3. Navigation

4.3.1. Ultra XR Navigation

4.3.1.1. Key Requirements

- **Data Volume:**
 - Captured Data: Up to 120 Mbps per XR device, total XR devices of up to 100,000
 - Presented Data: 4~8 Gbps video stream per XR Device
- **Data Velocity:**
 - TTP: 16 ms to 33 ms for reaching a smoothing screen update (30 fps ~ 60 fps)
- **Other aspects:**
 - Network Jitter / Reliability: 1 ms jitter, 99.9999% reliability

4.3.1.2. Assumptions

- **Common:**
 - high reliability and QoS (Ultra-low latency and jitter) ensure synchronized rendering of 3D model, and video response
 - OTA access network can be either cellular network or WiFi. A cellular network is assumed as it has less dependence on location
- **Captured Data:**
 - up to 120 Mbps per XR device (LiDAR = 70 Mbps Camera = 40 Mbps, GPS = 50 Kbps [Winter, 2017]). This 120 Mbps is the maximum possible value, and not all sensed data will be required in most conditions.
- **Presented Data:**
 - 8K uncompressed stream in 120-fps could be up 72~144Gbps

4.4. Human Augmentation

4.4.1. Mind-to-Mind Communication

4.4.1.1. Key Requirements

- **Data Volume:**
 - Data Size: possibly < 290 Gbps (144 Gbps [for a 8K/120 Hz video] * 2 and 9.2 Mbps [for 192 kHz, 24 bit, 2 channel audio] and additional data for other sensors
- **Data Velocity:**
 - TTP (via auditory sensing): the order of 100 ms
 - TTP (via visual sensing): the order of 10 ms

4.4.1.2. Assumptions

Calculations of the psychological state of a physical person must be done quickly enough so as not to interfere with smooth human communications/dialogs.

4.4.2. Another Me

4.4.2.1. Key Requirements

- **Data Volume:**
 - Data Size: possibly < 290 Gbps (144 Gbps [for a 8K/120 Hz video] * 2 and 9.2 Mbps [for 192 kHz, 24 bit, 2 channel audio] and additional data for other sensors.
- **Data Velocity:**
 - TTP (via auditory sensing): the order of 100 ms
 - TTP (via visual sensing): the order of 10 ms

4.4.2.2. Assumptions

All transactions between a person and computed result in digital space must be made instantaneously to facilitate smooth communication.

5. References

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History

Revision	Release Date	Summary of Changes
1.0	October 21, 2021	Initial Release