# Toward next-generation holographic communications in 6G Smart Networks

**Mario Montagud (@mario_Montagud)**
Ramón y Cajal Scientist

# Outline

- **About us**

- From 2D conferencing to 3D holographic comms

- State-of-the-art and limitations

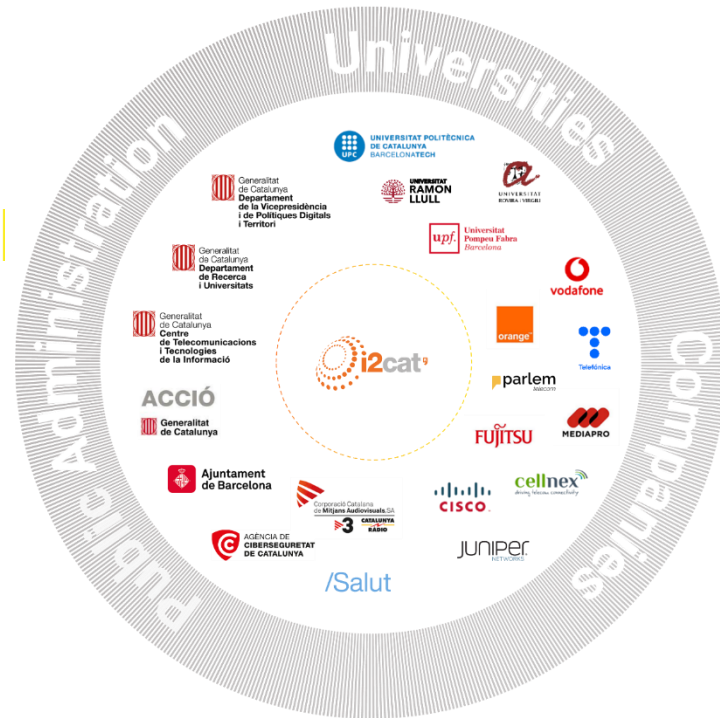- Holographic comms over Computing Continuum and 6G

- Conclusions and Future Work

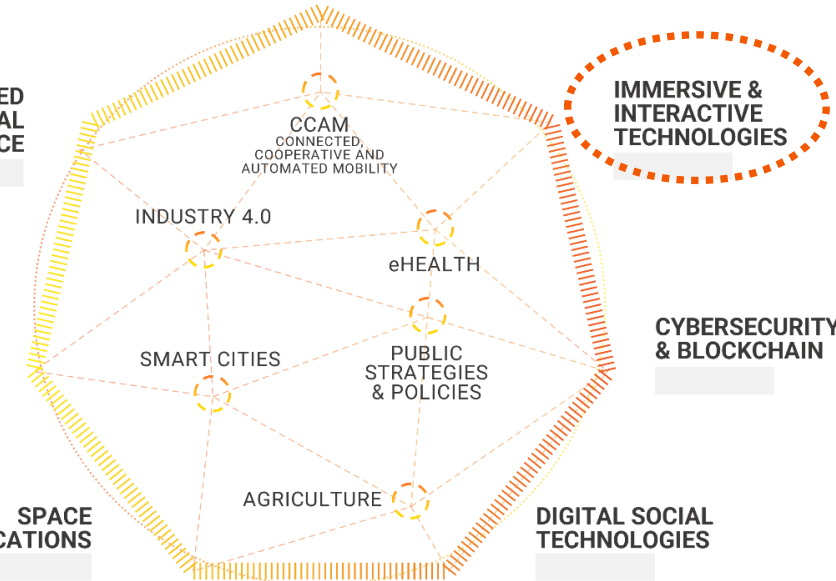# About us

>200 employees
~25% PhD

% Anual income:
~16M€

**XR**

**6G**



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**Universities**

**Public Administration**

**Companies**

Generalitat de Catalunya
Departament de la Vicepresidència i de Polítiques Digitals i de Territori

Generalitat de Catalunya
Departament de Recerca i Universitats

Generalitat de Catalunya
Centre de Telecomunicacions i Tecnologies de la Informació

ACCIÓ
Generalitat de Catalunya

Ajuntament de Barcelona

AGÈNCIA DE CIBERSEGURETAT DE CATALUNYA

/Salut

UPC UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

UNIVERSITAT RAMON LLULL

UNIVERSITAT ROVIRA I VIRGILI

upf. Universitat Pompeu Fabra Barcelona

i2cat

vodafone

orange

Telefónica

parlem

FUJITSU

MEDIAPRO

CISCO

cellnex

3 CATALUNYA RÀDIO Corporació Catalana de Mitjans Audiovisuals SA

JUNIPER NETWORKS

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**SMART NETWORKS AND SERVICES**
**6G, 5G, IoT**

**DISTRIBUTED ARTIFICIAL INTELLIGENCE**

**IMMERSIVE & INTERACTIVE TECHNOLOGIES**

CCAM
CONNECTED, COOPERATIVE AND AUTOMATED MOBILITY

INDUSTRY 4.0

eHEALTH

**ARTIFICIAL INTELLIGENCE DRIVEN SYSTEMS**

SMART CITIES

PUBLIC STRATEGIES & POLICIES

**CYBERSECURITY & BLOCKCHAIN**

AGRICULTURE

**SPACE COMMUNICATIONS**

**DIGITAL SOCIAL TECHNOLOGIES**

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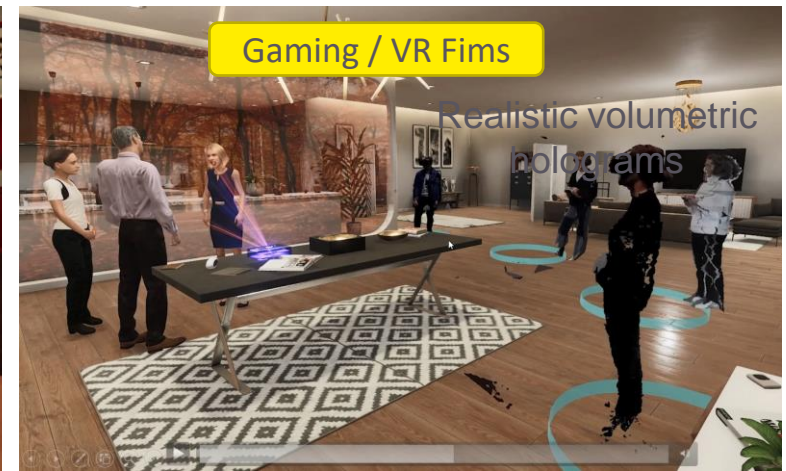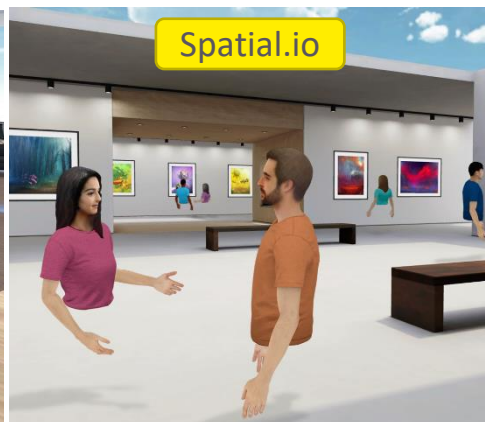
- Conclusions and Future Work
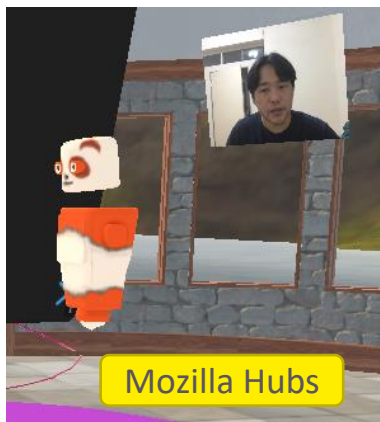
# Toward a new era in digital comms

# Use Cases: not just entertainment…



Virtual Meetings

Live ingest from Cloud Production Platform

Hographic representation of the presenter

Webcam User

Holographic representations of collaborators or VIP clients

Training

3D Model of presented Market Product

Live Shopping

Virtual TV Shows

Virtual Visits

Culture

Gaming / VR Fims

Realistic volumetric holograms

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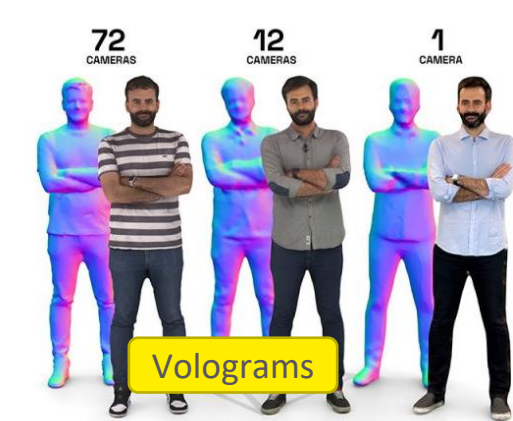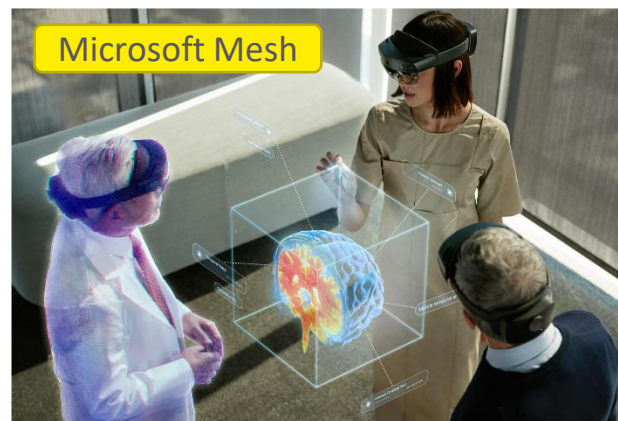- Conclusions and Future Work

# Social VR platforms: State-of-the-art

**Avatars**

Mozilla Hubs

Virbela

Spatial.io

Facebook Spaces

Facebook Meta

**Holograms**

Microsoft

Microsoft Mesh

Volograms

Matsuko

**EU Companies**

# HoloMIT: Our Social VR / holographic comms platform

**ViVIM**
Visió per computador per
Vídeo Immersiu Multi-plataforma

6-8 Mbps per User
Up to 6-8 Users per Session

**VRTogether**

>50 Mbps per User
GPU-compliant coding

**REVOLUTION** **xReco**



Webcam Users

Single Camera Point Clouds

**i2cat** **nem** New European Media
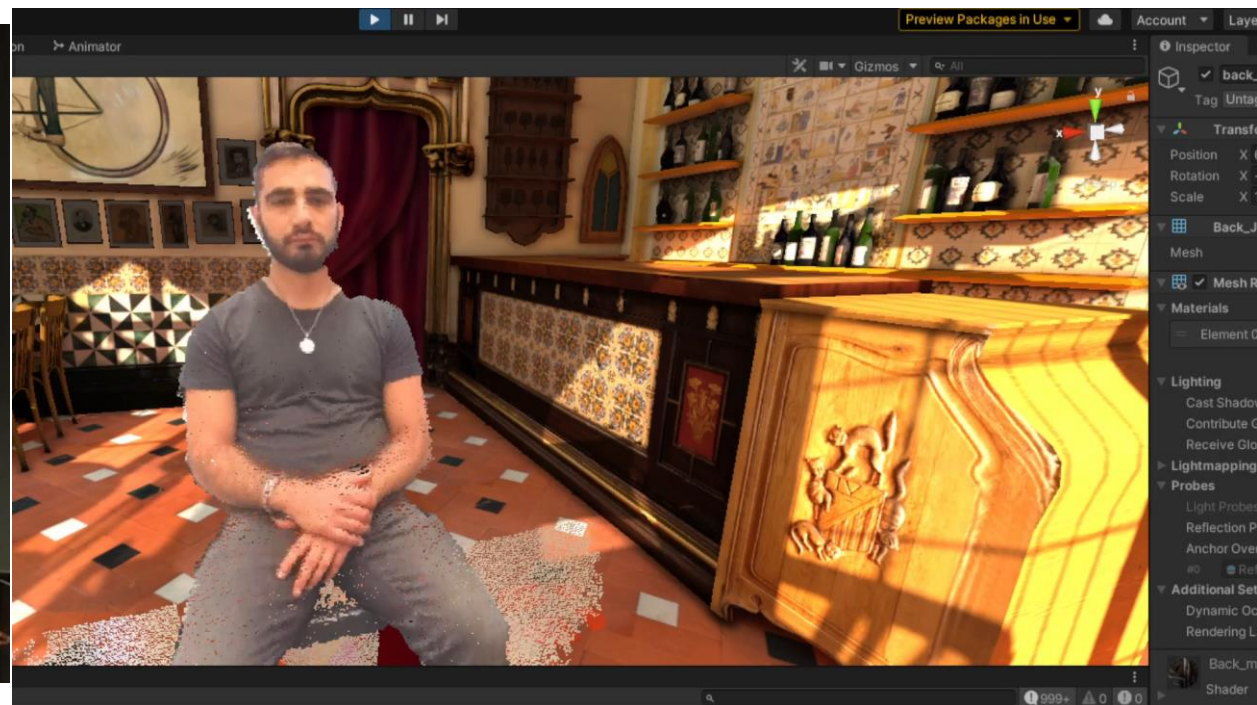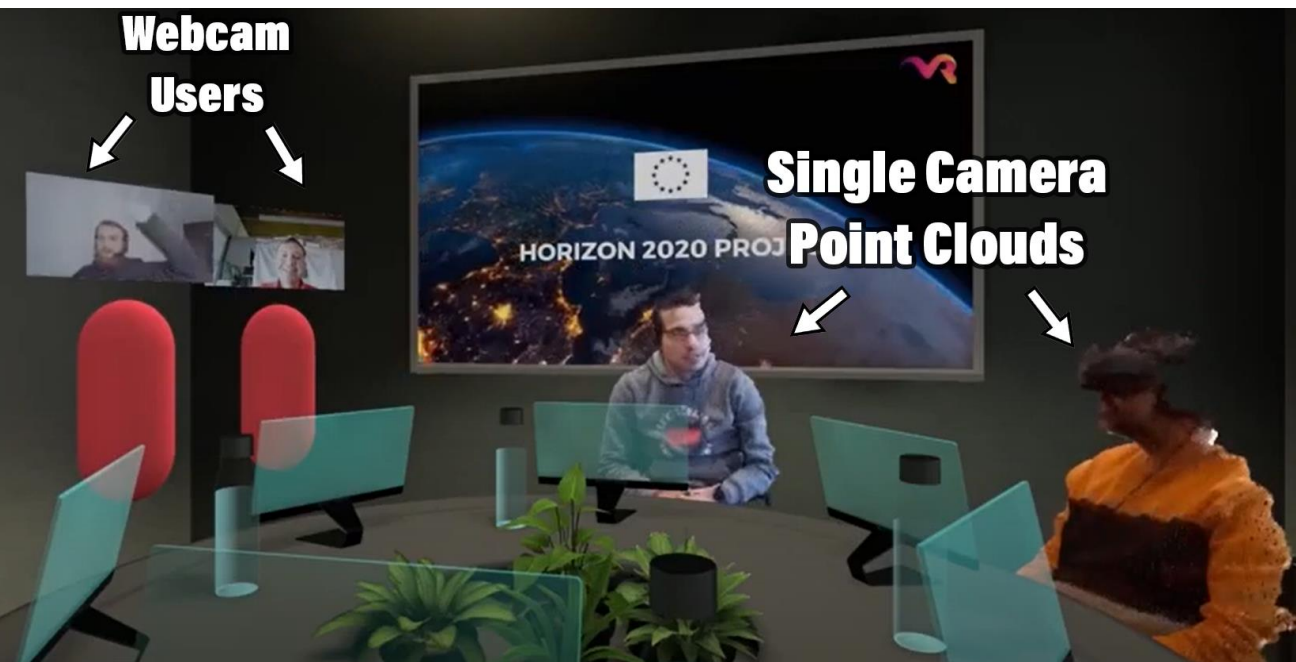
# Advances… but not yet there!

- Key remaining challenges and limitations

  - Visual Quality

  - Resources Usage

  - Cost / Deployment Complexity

  - Scalability

  - Interoperability

- (Toward) 6G Smart Networks to the Rescue!

  - Latency

  - Bandwidth

  - Computing Continuum / Smart Orchestration

  - Dynamic Reconfiguration / Quality on Demand (QoD)
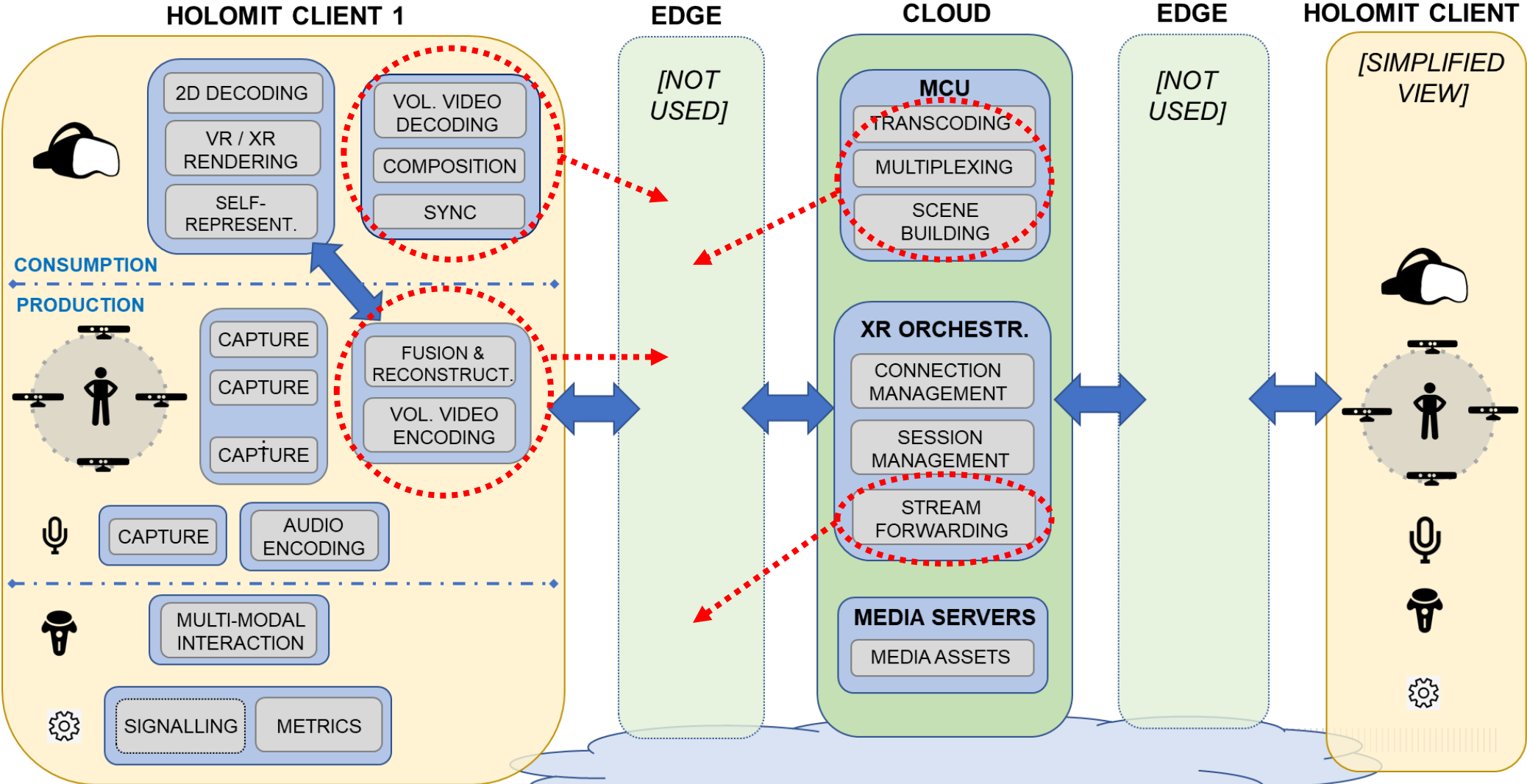
  - Reliability & Trustworthiness

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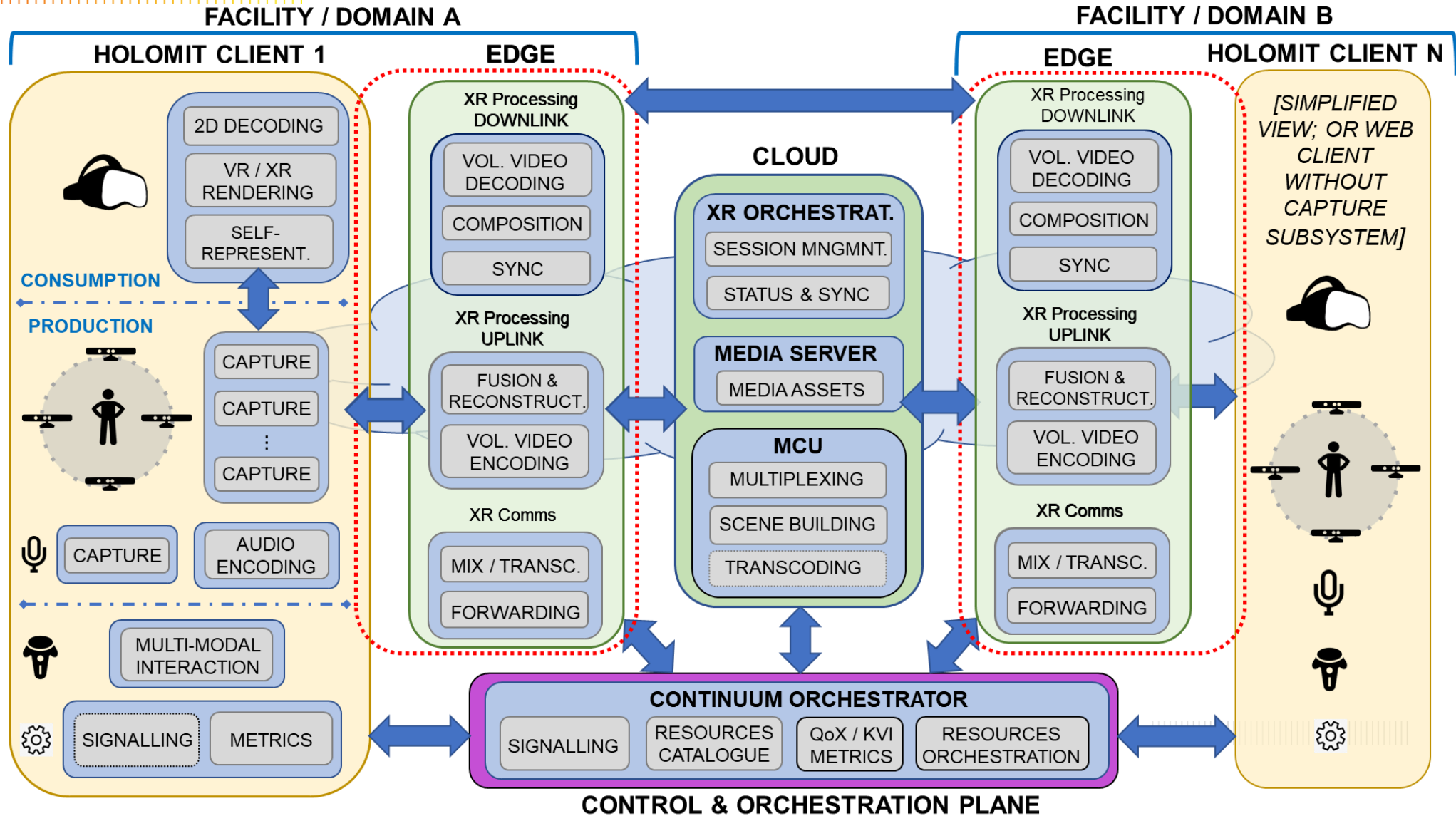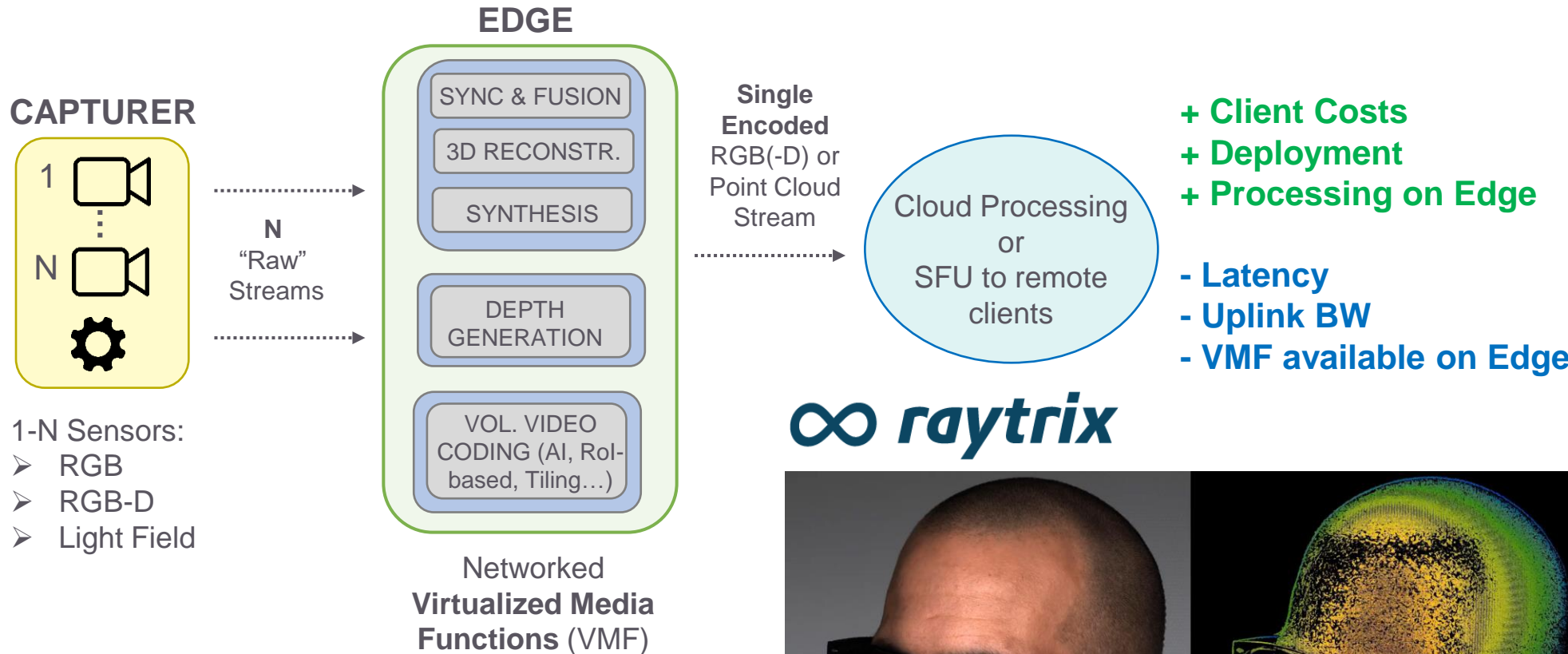- Conclusions and Future Work

# HoloMIT 'as it is' now

# HoloMIT with Virtualized Media Functions (VMF) over the (6G) Computing Continuum

# Edge-assisted Processing: 3D Content Production (Uplink)

**CAPTURER**

1

N

1-N Sensors:
➢ RGB
➢ RGB-D
➢ Light Field

**N**
"Raw"
Streams

**EDGE**

SYNC & FUSION

3D RECONSTR.

SYNTHESIS

DEPTH GENERATION

VOL. VIDEO CODING (AI, RoI-based, Tiling…)

Networked
**Virtualized Media Functions** (VMF)

**Single Encoded**
RGB(-D) or Point Cloud Stream

Cloud Processing or SFU to remote clients

**+ Client Costs**
**+ Deployment**
**+ Processing on Edge**

**- Latency**
**- Uplink BW**
**- VMF available on Edge**

∞ raytrix

MATSUKO

# Edge-assisted Processing: 3D Content Consumption (Downlink)

**LIGHTWEIGHT WEB CLIENTS**

**EDGE**

**CLOUD**

**Passive** Audio+Video Consumption

*M* **Passive** Rendering Instances

3D Virtual Environment Download or Streaming

**MEDIA SERVER(S)**

3D VR ASSETS

2D CoD + LIVE MEDIA ASSETS

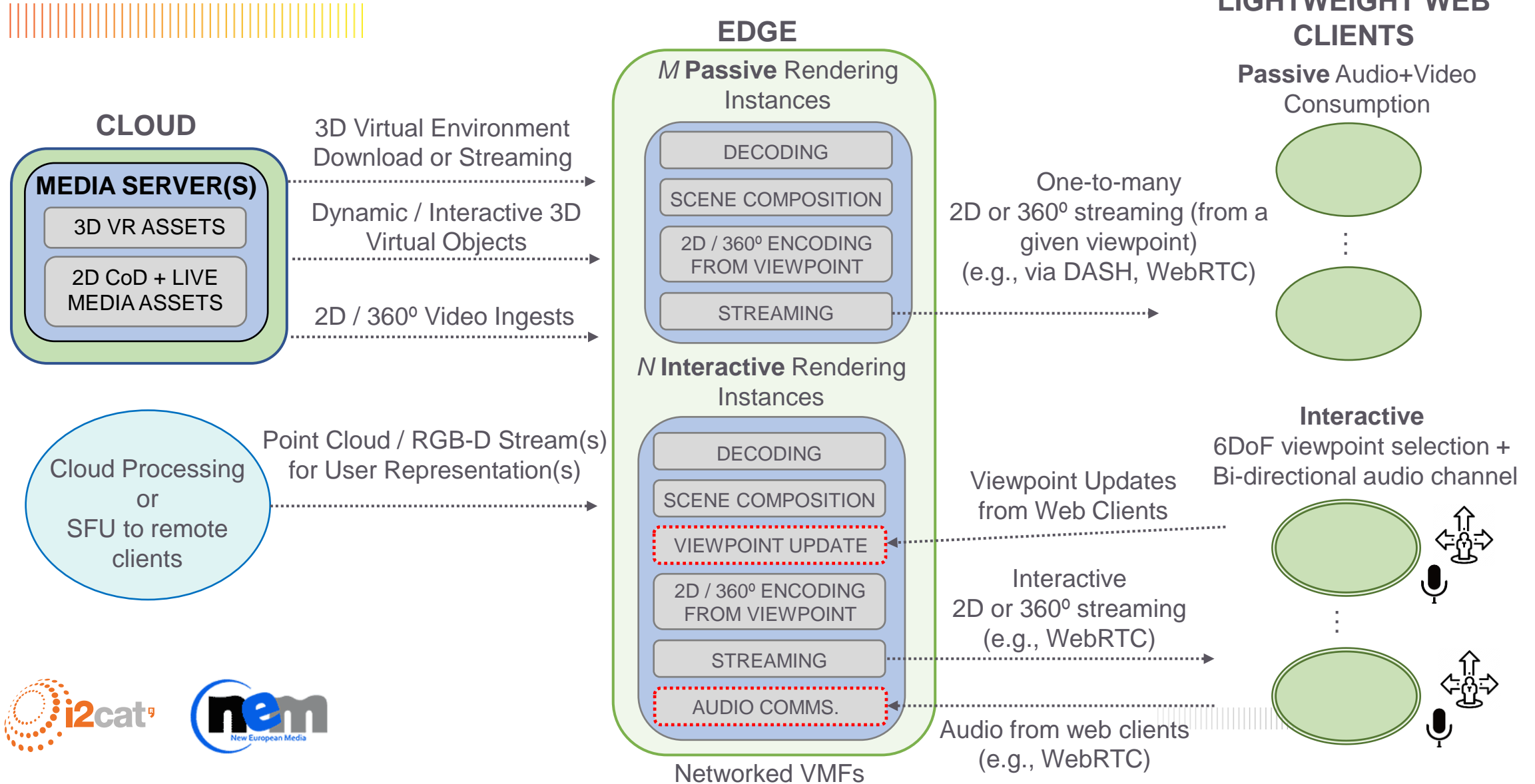Dynamic / Interactive 3D Virtual Objects

2D / 360º Video Ingests

DECODING

SCENE COMPOSITION

2D / 360º ENCODING FROM VIEWPOINT

STREAMING

One-to-many
2D or 360º streaming (from a given viewpoint)
(e.g., via DASH, WebRTC)

*N* **Interactive** Rendering Instances

Point Cloud / RGB-D Stream(s) for User Representation(s)

Cloud Processing or SFU to remote clients

DECODING

SCENE COMPOSITION

VIEWPOINT UPDATE

2D / 360º ENCODING FROM VIEWPOINT

STREAMING

AUDIO COMMS.

**Interactive**
6DoF viewpoint selection + Bi-directional audio channel

Viewpoint Updates from Web Clients

Interactive
2D or 360º streaming
(e.g., WebRTC)

Audio from web clients
(e.g., WebRTC)

Networked VMFs

# Edge-assisted Processing: 3D Content Consumption (Downlink)

**CLOUD**

**LIGHTWEIGHT WEB CLIENTS**

**Interactive**
6DoF viewpoint selection +
Bi-directional audio channel

**MEDIA SERVER(S)**

3D VR ASSETS

2D CoD + LIVE MEDIA ASSETS

3D Virtual Environment Download or Streaming

Dynamic / Interactive 3D Virtual Objects

2D / 360º Video Ingests

*(Optionally)*

**EDGE**

*N* **Interactive** Rendering Instances

DECODING

SCENE COMPOSITION

VIEWPOINT UPDATE

VOLUMETRIC VIDEO PROJECTION

STREAMING

AUDIO COMMS.

Networked VMFs

Cloud Processing or SFU to remote clients

Point Cloud / RGB-D Stream(s) for User Representation(s)

**+ Client Costs**
**+ Deployment**
**+ Processing on Edge**

**- Latency**
**- Scalability on Edge**
**- VMF available on Edge**

Viewpoint Updates from Web Clients

Single Point Cloud or RGB-D Stream (from viewpoint

Audio from web clients (e.g., WebRTC)

i2cat
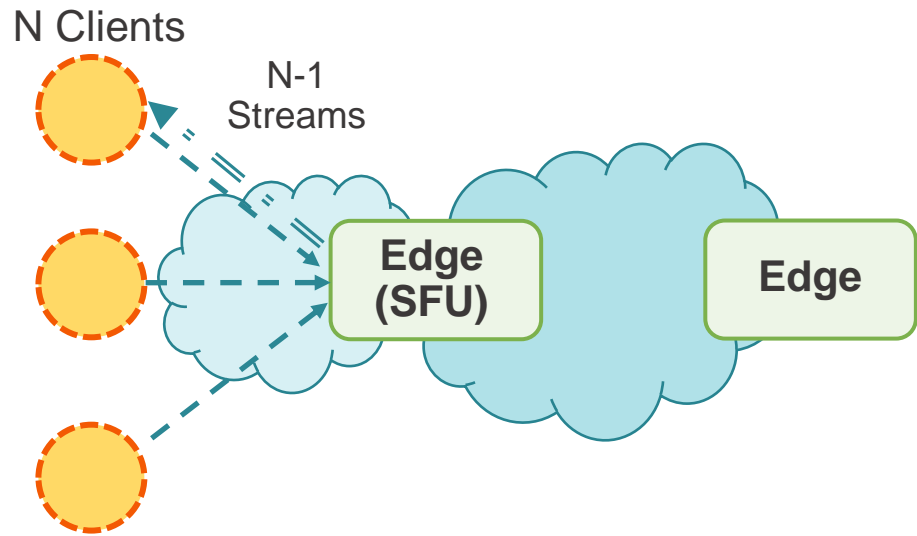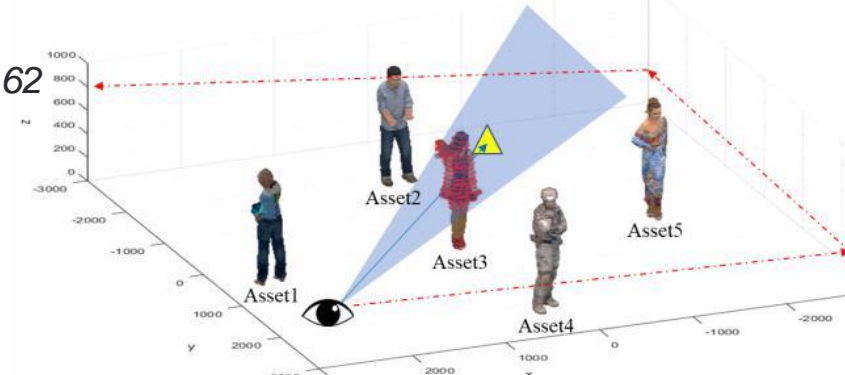
nem
New European Media

# Edge-assisted Comms: Stream Forwarding + Clustering

- Selection of best Edge (hops, delay, energy, GPU…)
- Users' Clustering based on geographical, on virtual location, on types, on roles
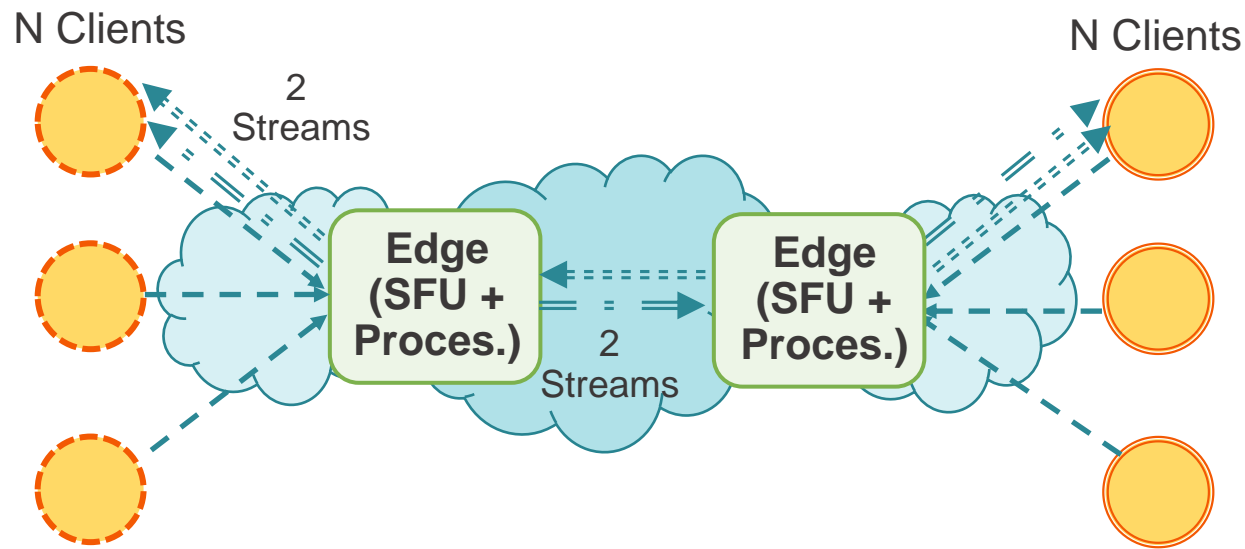    - One or multiple SFU (+ Mixing) (+ Transcoding) (+Remote Rendering)

*Park, J., Chou, P. A., & Hwang, J. N. (2019). Rate-utility optimized streaming of volumetric media for augmented reality. IEEE Journal on Emerging and Selected Topics in Circuits and Systems, 9(1), 149-162*
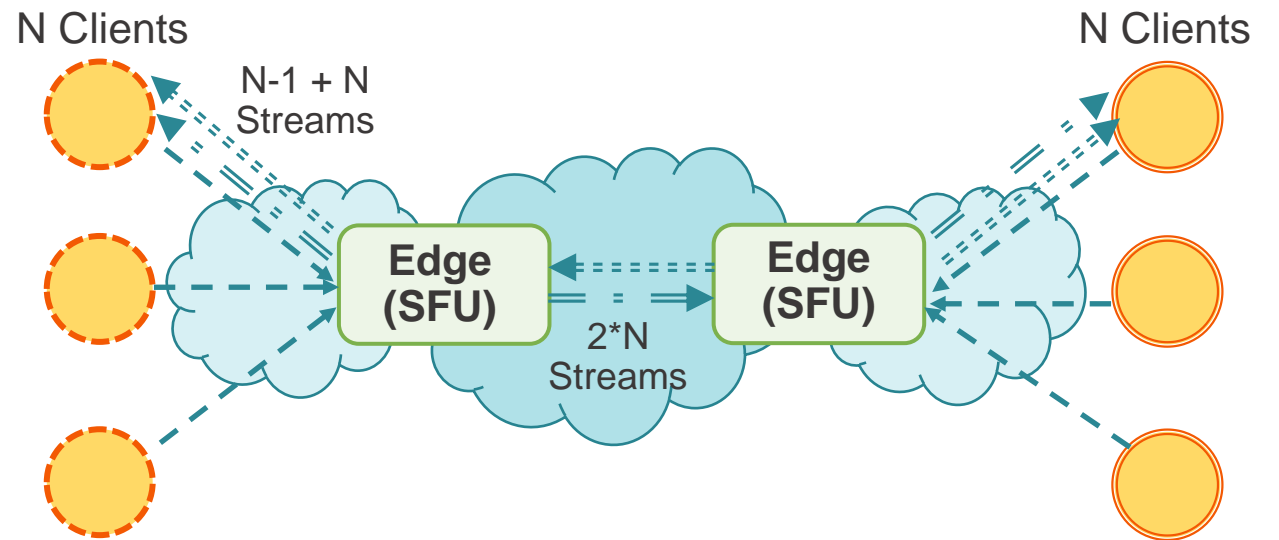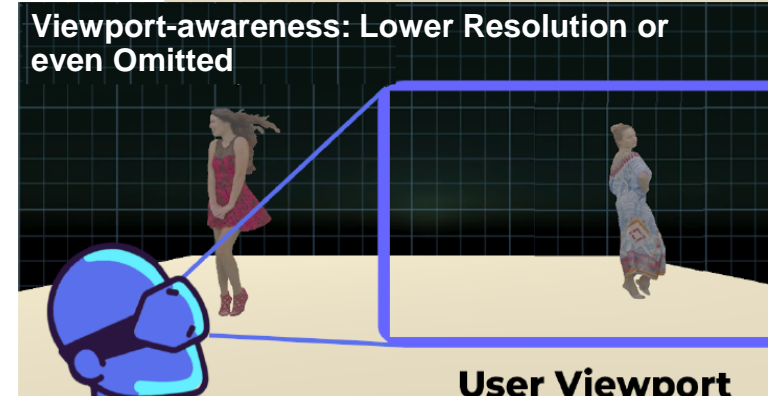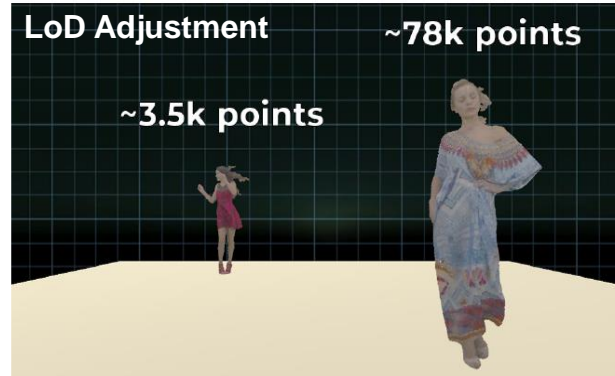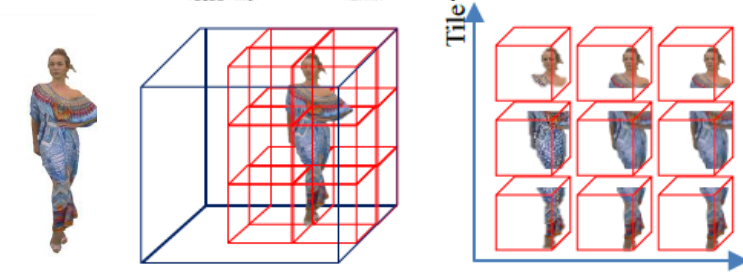
## Edge-assisted Comms: Mixing + Transcoding

- Beyond forwarding and clustering, streams can be mixed and transcoded on the Edge (Cloud)
  - Partial scene building / rendering + Caching
  - Tiling / Level of Detail (LoD) adjustment / selection
  - Viewport-aware / RoI-based processing



N Clients

2 Streams

N Clients

Edge (SFU + Proces.)

2 Streams

Edge (SFU + Proces.)

**+ Client Costs**
**+ Deployment**
**+ Processing on Edge**

**- Latency**
**- Scalability on Edge**
**- VMF available on Edge**

LoD Adjustment ~78k points

~3.5k points

Viewport-awareness: Lower Resolution or even Omitted

User Viewport

Asset1 Asset2 Asset3 Asset4 Asset5

Tile

i2cat

nem New European Media

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- **Conclusions and Future Work**

# Conclusions and Future Work

- Holograpics comms are a key enabler toward the Metaverse
  - Remaining challenges and limitations
  - Proven benefits and potential
- On the road toward 6G, but envisioned opportunities in terms of…
  - Performance
  - Computing Continuum / Smart Orchestration
  - Elastic Reconfiguration / Quality on Demand (QoD)
  - Reliability & Trustworthiness
- Future Work
  - Implement the presented roadmap
  - Follow closely and leverage advances on 6G
  - Consider the environment. Metaverse = Users + Environment

# Thank you!

*Questions? Comments?*

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