

Fraunhofer FOKUS Institute for Open Communication Systems

Efficient Rendering and Streaming of Virtual Worlds in the Web4.0 Era

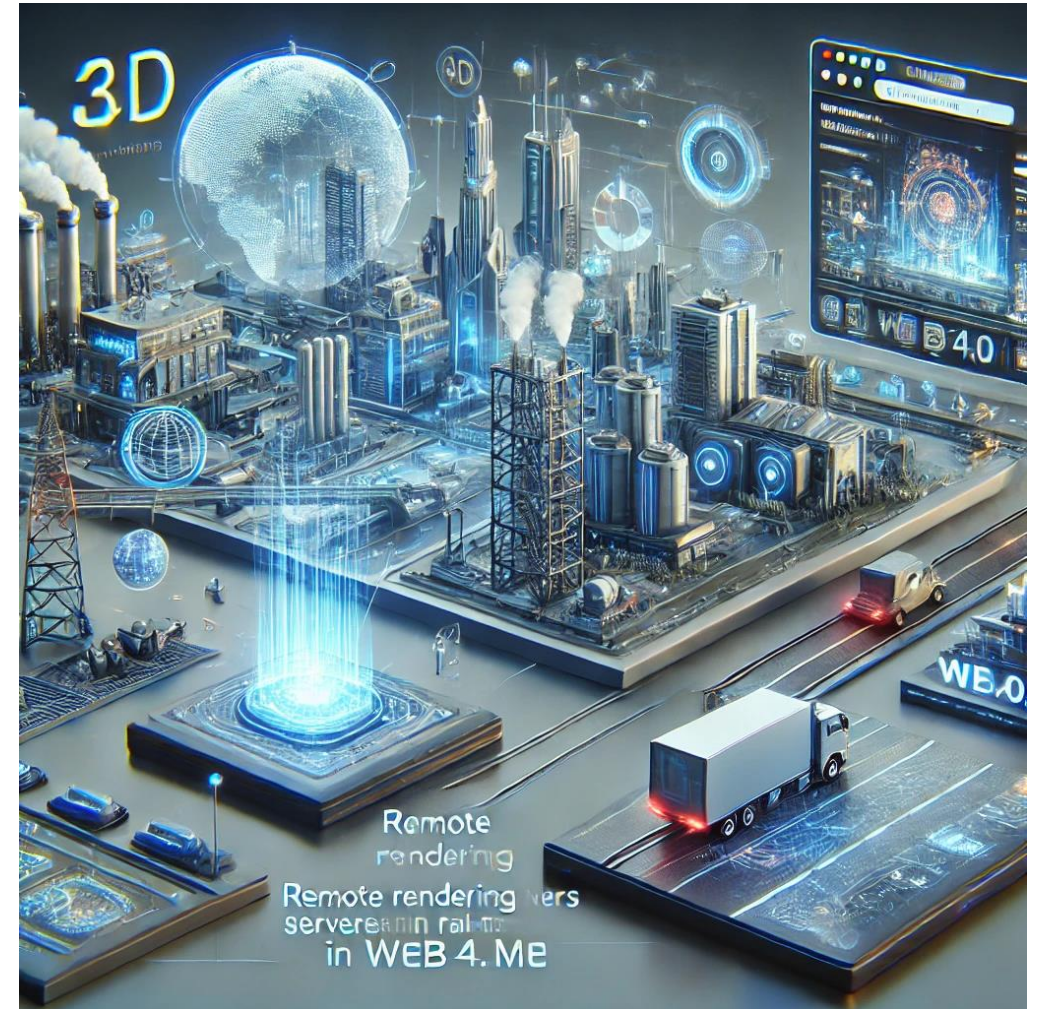
Dr.-Ing. Louay Bassbouss (Fraunhofer FOKUS)

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Efficient Rendering and Streaming of Virtual Worlds in the Web4.0 Era

Introduction

- Web4.0 represents the evolution of the internet, characterized by immersive virtual worlds and advanced intelligent applications becoming integral to everyday interactions.
- Virtual worlds require massive computing resources. Efficient rendering and streaming are crucial to meet the demands of real-time applications like industrial digital twins, traffic simulations, training platforms, virtual AI Assistants and many other.
- Key Areas:
 - Remote Rendering: Offloading complex computations to powerful remote servers to reduce device-side load.
 - Streaming Technologies: Ensuring seamless, high-quality visual experiences, even for data-heavy applications.
 - Sustainability: How efficient rendering and streaming contribute to reducing energy consumption in large-scale deployments.



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Use Cases

Industrial Applications:

- Virtual replicas of machinery for real-time monitoring and diagnostics.
- Interaction with complex systems via immersive environments.

Digital Twins:

- Real-time synchronization of physical assets with their virtual counterparts for predictive maintenance, simulations, and operational optimizations.

Traffic Simulations:

- Simulation of traffic flows in urban areas, critical for autonomous driving research and smart city planning.
- Real-time adjustments using remote-rendered virtual environments.

Training Simulations:

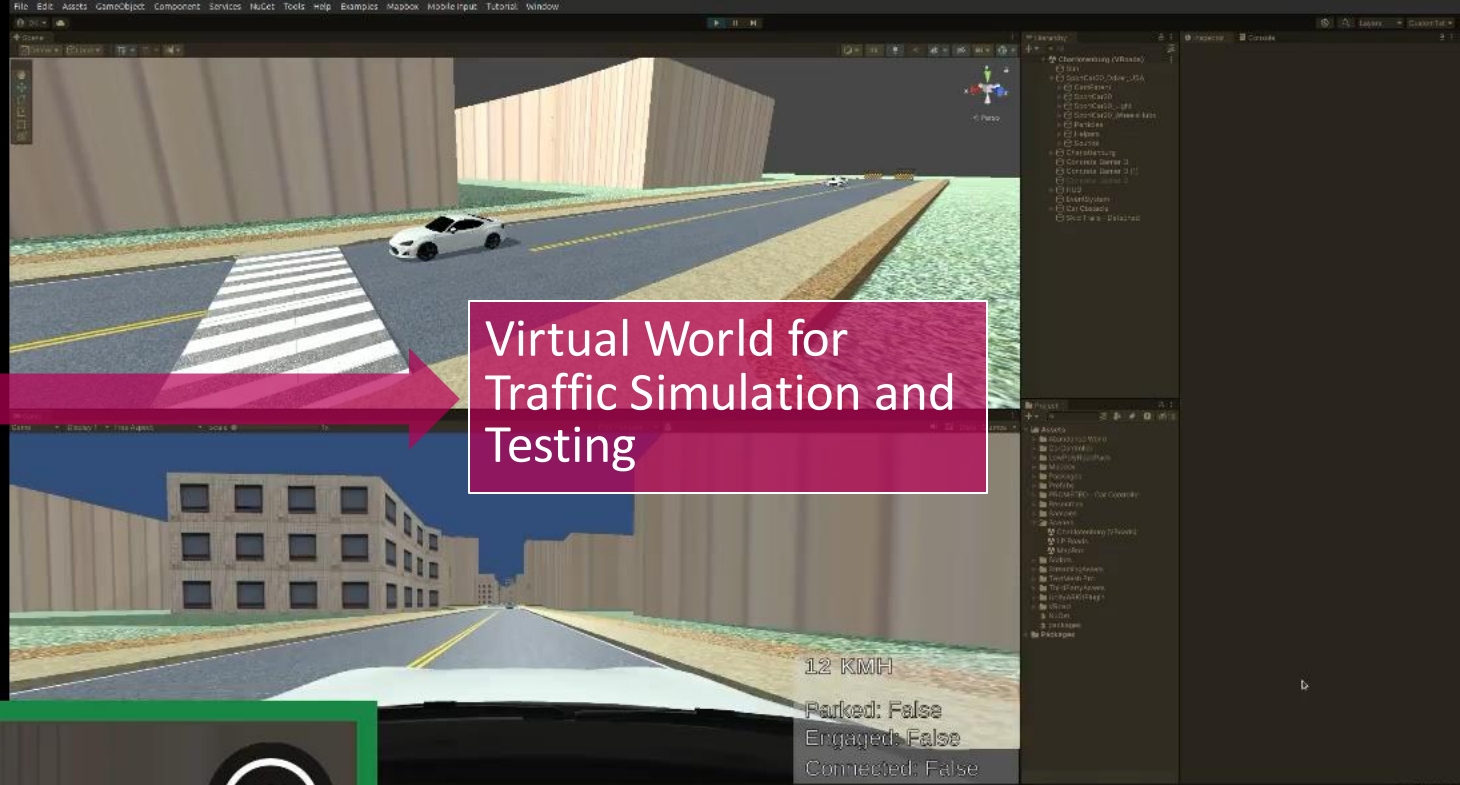
- Remote-rendered training for high-risk industries like aviation, healthcare, or engineering.
- Hands-on experience in a virtual environment, reducing physical resource requirements.



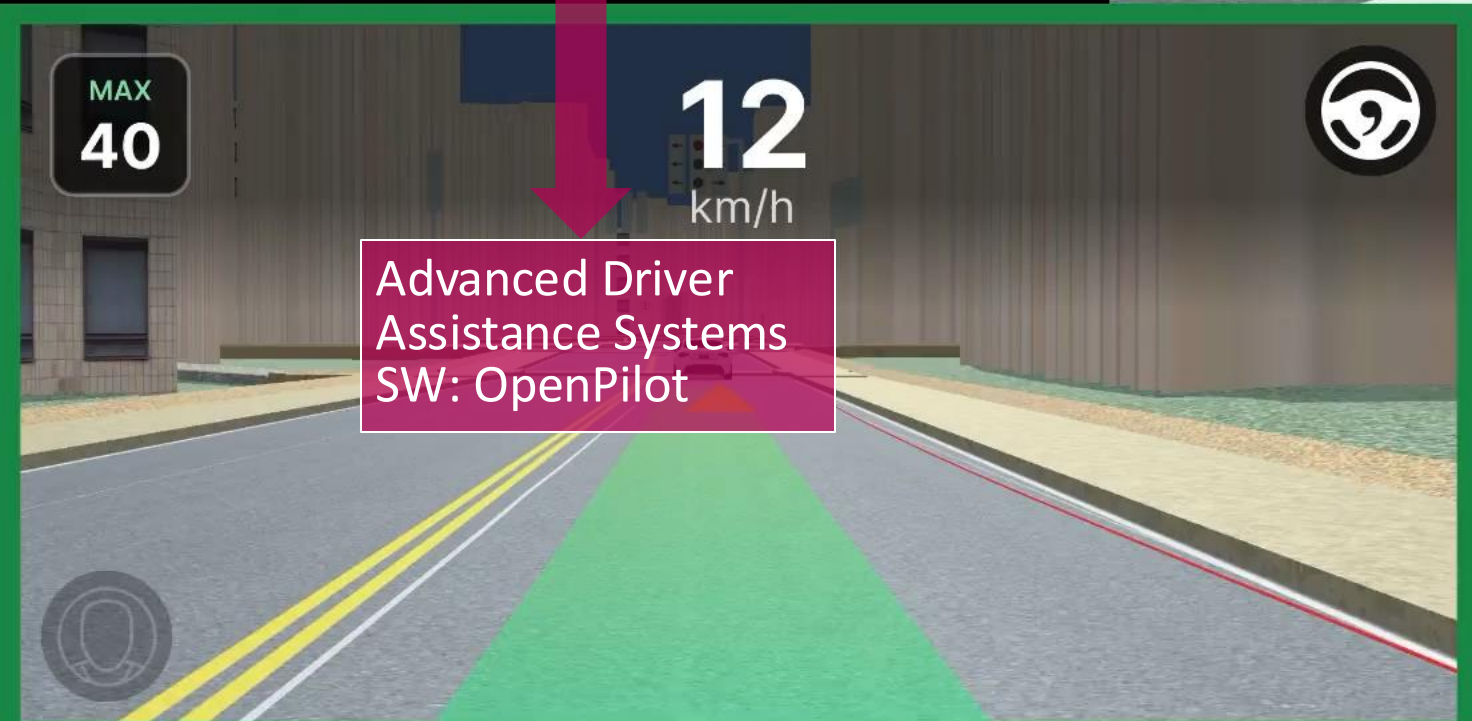
Example: Traffic Simulation

```
Ctrl to Unity: acc= 0.459, str=-0.162 | State to OP: ( -0, 0, 0) (-46, 69) 90 25 0 1  
Ctrl to Unity: acc= 0.461, str= 1.000 | State to OP: ( 1, 0, -0) (-46, 69) 90 25 0 0  
Ctrl to Unity: acc= 0.462, str=-0.067 | State to OP: ( 1, -0, -0) (-46, 69) 90 25 0 0  
Ctrl to Unity: acc= 0.465, str=-0.049 | State to OP: ( 1, 0, -0) (-46, 69) 90 25 0 0  
Ctrl to Unity: acc= 0.480, str=-0.049 | State to OP: ( 2, -0, -0) (-46, 69) 90 25 0 0  
Ctrl to Unity: acc= 0.495, str=-0.029 | State to OP: ( 3, -0, -0) (-45, 69) 91 25 0 0  
Ctrl to Unity: acc= 0.507, str=-0.143 | State to OP: ( 4, -0, -0) (-45, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.463, str=-0.037 | State to OP: ( 4, -0, -0) (-45, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.442, str= 0.086 | State to OP: ( 4, -0, -0) (-44, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.463, str= 0.086 | State to OP: ( 4, -0, -0) (-44, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.477, str= 0.086 | State to OP: ( 4, -0, -0) (-44, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.490, str= 0.014 | State to OP: ( 4, -0, -0) (-43, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.501, str= 0.086 | State to OP: ( 4, -0, -0) (-42, 69) 92 25 0 0  
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Ctrl to Unity: acc= 0.537, str= 0.086 | State to OP: ( 4, -0, -0) (-41, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.549, str= 0.037 | State to OP: ( 4, -0, -0) (-40, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.558, str= 0.037 | State to OP: ( 4, -0, -0) (-40, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.568, str= 0.038 | State to OP: ( 4, -0, -0) (-40, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.576, str= 0.039 | State to OP: ( 4, -0, -0) (-40, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.583, str= 0.042 | State to OP: ( 4, -0, -0) (-39, 69) 92 25 0 0  
Ctrl to Unity: acc= 0.588, str= 0.036 | State to OP: ( 3, -0, -0) (-39, 69) 92 25 0 0  
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```

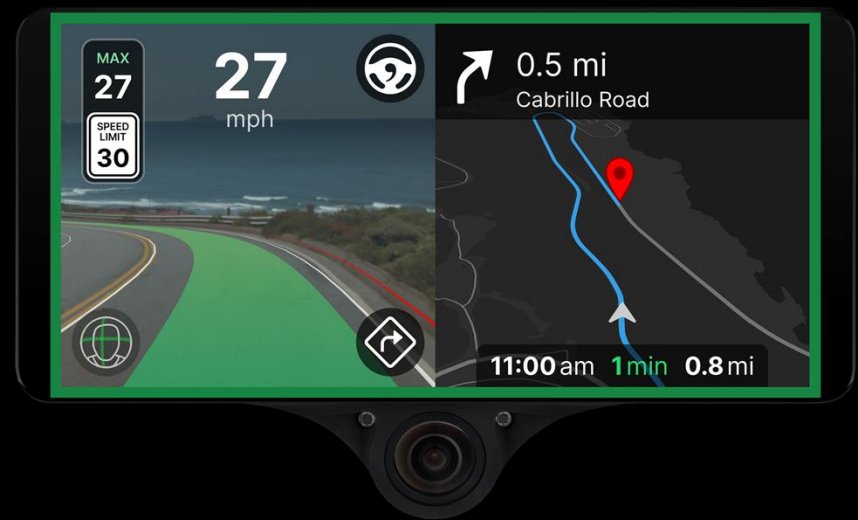
Connection Virtual Worlds to Traffic Simulation



Virtual World for Traffic Simulation and Testing



Advanced Driver Assistance Systems SW: OpenPilot



Virtual Worlds

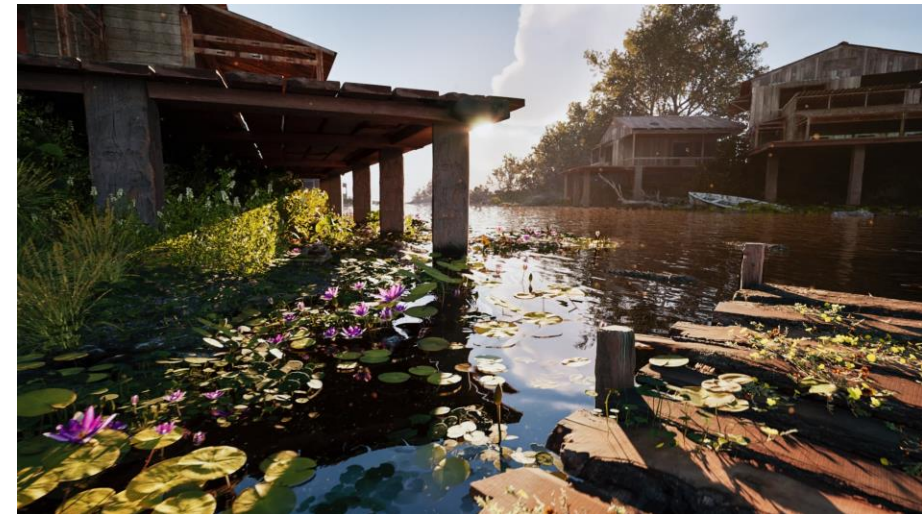
Enabler Tools and Engines – Unity and Unreal Engine

- The two most popular Graphics Engines
- Market share of >50% among the two engines
- Asset Stores offer
 - Community-made 3D assets
 - 3D assets provided by professional developers
 - Paid and free libraries



Source: <https://blog.unity.com/technology/creating-immersive-photorealistic-vr-experiences>

[-with-the-high-definition-render](#)

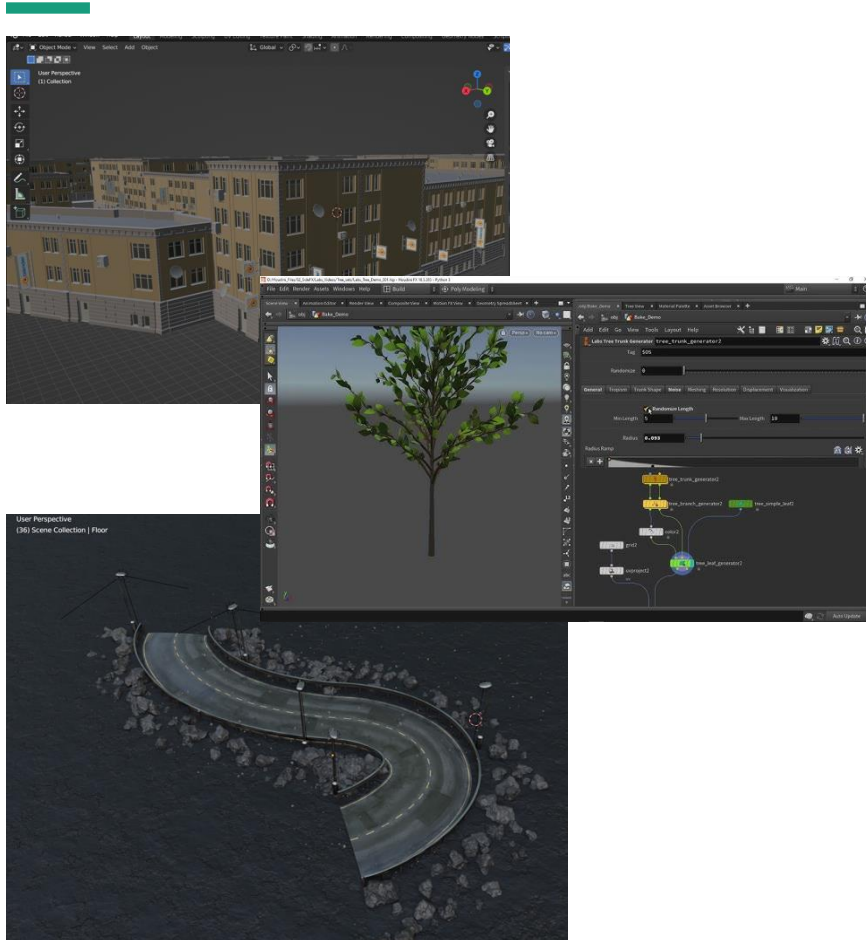


Source: [https://forums.unrealengine.com/t/unreal-engine-5-1-photorealistic-scene-the-river-](https://forums.unrealengine.com/t/unreal-engine-5-1-photorealistic-scene-the-river-lumen-nanite/1297150)

[lumen-nanite/1297150](#)

Virtual Worlds

Generation from existing datasets



building_m	source	building_u	building_l	building_c	building_s	name	building
13225	Open Citi...	utility	2	average	RCC_with_b...	Animal Res...	yes
13229	Open Citi...	utility	3	average	RCC_with_b...	Medicine St...	yes
13232	Open Citi...	utility	4	average	RCC_with_b...	Medicine St...	yes
13236	Open Citi...	utility	1	average	RCC_with_b...	Office of As...	yes
13292	Open Citi...	utility	1	poor	RCC_withou...	NULL	yes
13564	Open Citi...	utility	1	average	brick	NULL	yes
13600	Open Citi...	utility	1	average	brick	NULL	yes
13712	Open Citi...	utility	1	good	brick	NULL	yes
13762	Open Citi...	utility	1	average	RCC_with_b...	Office of Pr...	yes
13763	Open Citi...	utility	1	average	RCC_withou...	Animal Bur...	yes
13769	Open Citi...	utility	1	poor	RCC_withou...	NULL	yes
14592	Open Citi...	utility	1	average	RCC_with_b...	NULL	yes
12537	Open Citi...	unused	2	poor	brick	NULL	yes
12559	Open Citi...	unused	1	poor	RCC_with_b...	NULL	yes



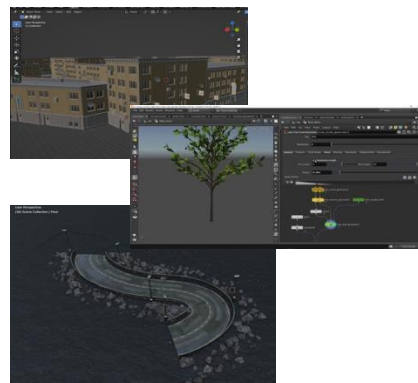
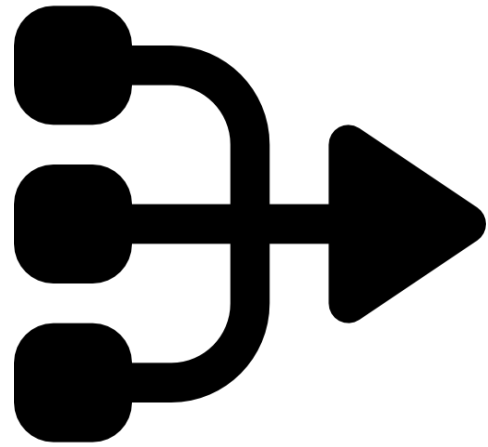
OpenStreetMap

Virtual Worlds

Generation from existing datasets



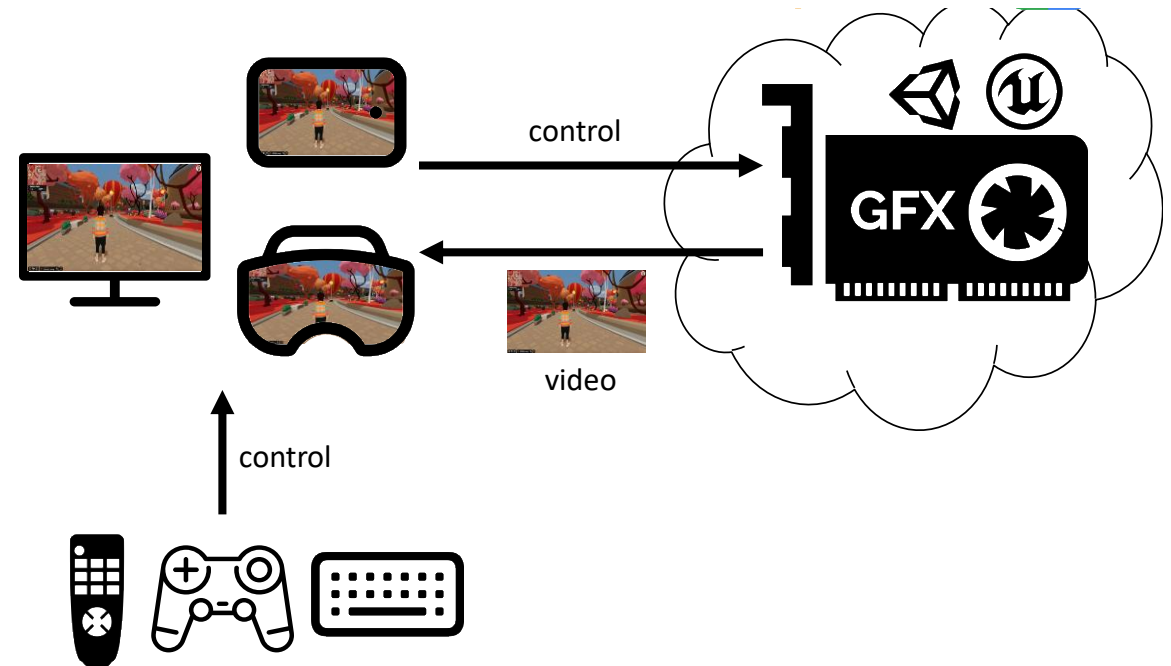
building_id	source	building_w	building_h	building_s	building_e	name	building	
13321	plaster	Open Cti	utility	2	average	RCC_with_3	Animal Res.	yes
13328	plaster	Open Cti	utility	3	average	RCC_with_3	Medicine St.	yes
13332	plaster	Open Cti	utility	4	average	RCC_with_3	Medicine St.	yes
13338	plaster	Open Cti	utility	3	average	RCC_with_3	Office of Ar.	yes
13340	plaster	Open Cti	utility	3	poor	RCC_without	NULL	yes
13364	brick	Open Cti	utility	3	average	brick	NULL	yes
13369	plaster	Open Cti	utility	3	average	brick	NULL	yes
13372	plaster	Open Cti	utility	3	good	brick	NULL	yes
13383	plaster	Open Cti	utility	3	average	RCC_with_3	Office of Pr.	yes
13384	plaster	Open Cti	utility	3	average	RCC_without	Animal Bar.	yes
13388	plaster	Open Cti	utility	3	poor	RCC_without	NULL	yes
13403	plaster	Open Cti	utility	3	average	RCC_with_3	NULL	yes
13337	plaster	Open Cti	unmanned	2	poor	brick	NULL	yes
13316	plaster	Open Cti	unmanned	3	poor	RCC_with_3	NULL	yes



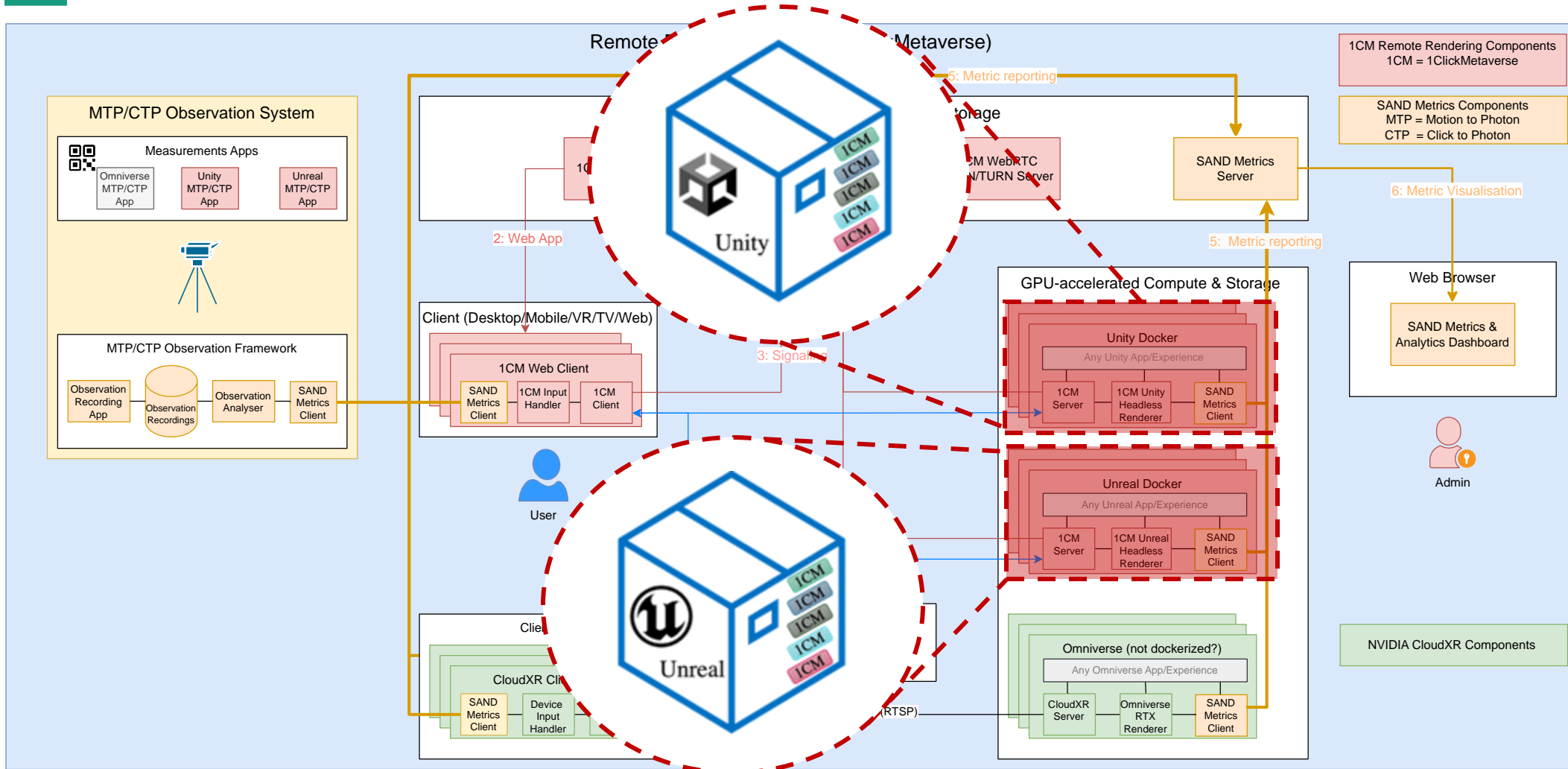
Local Rendering



Remote Rendering



Remote Rendering & Streaming Architecture



Remote Rendering and Streaming: Integration of Physical and Virtual Worlds

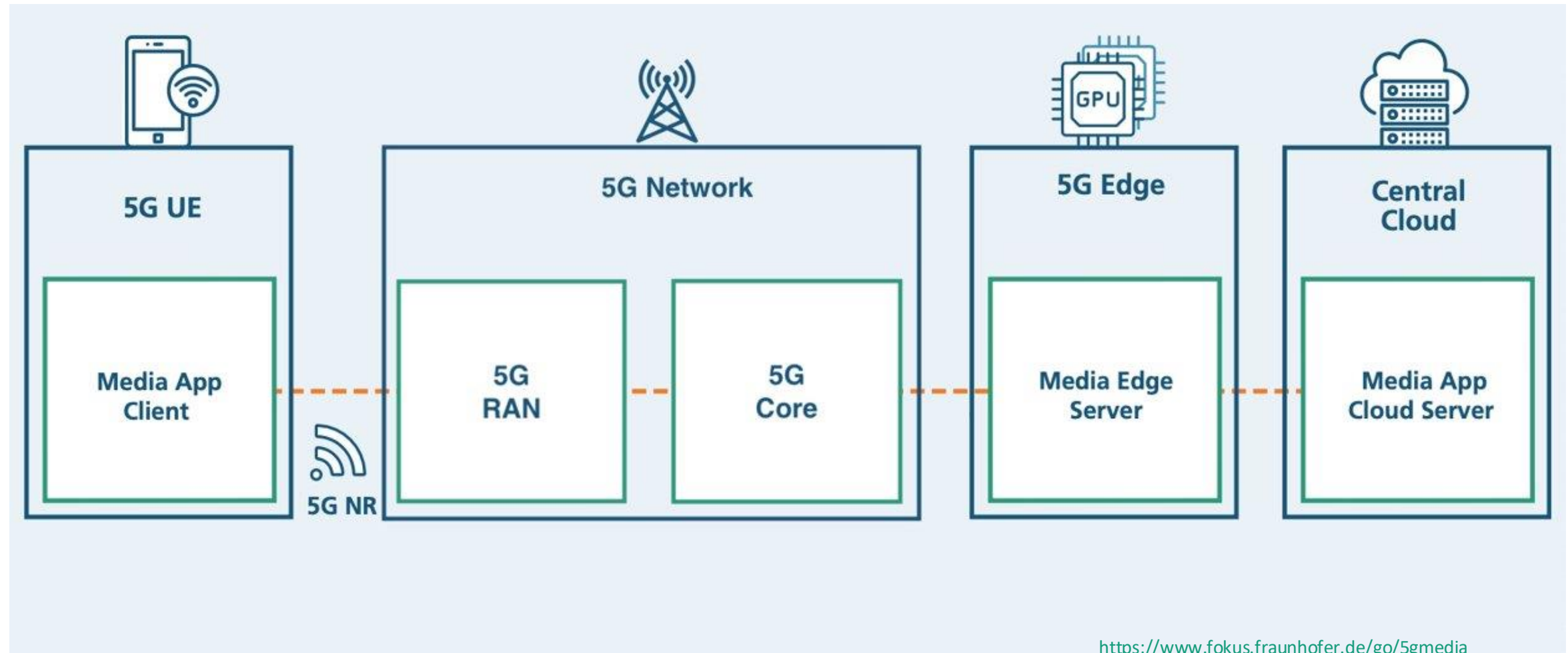


<https://www.fokus.fraunhofer.de/go/metaverse>



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Remote Rendering and Streaming in 5G (and 6G)



Virtual Worlds

Remote Rendering Testbed

3 Clients

System Memory: 32GB
CPU: 25.11%
GPU: Tesla V100-PCIe-32GB
Framerate: 76 FPS
Video Codecs: VP8, VP9, H.264, H.265
Audio Codecs: opus, AAC, MP3

name	rtt	rv
5G Android	140.00	5199
LTE iPhone	96.00	2184
Wifi Mac	31.00	3778

- Safari
- iOS/iPhone
- LTE
- Cloud Rendering

- Chrome
- Mac
- Wifi
- Cloud Rendering

- Chrome
- Android/Huawei
- 5G (SA)
- Edge Rendering

<https://www.fokus.fraunhofer.de/go/metaverse>

Contact

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Thank You
for your
attention!

