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CHARITY
Cloud for Holography and Augmented RealITY

Cloud for Holography and Cross Reality

D5.3: Market survey and interim exploitation plans

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Abstract

This Deliverable summarizes the main characteristics of the key markets addressed by CHARITY, first and foremost the ones relevant to AR/VR/holographic applications and services embodied by the CHARITY use cases, but also the infrastructure service market that might be positively impacted by the CHARITY results. Then it describes what has been to date detected as main potentially exploitable results of the project. Finally, all the CHARITY partners present their interim exploitation strategies, at the extent of detail compatible with the progress of technical developments. Exploitation plans are expected to be completed and finalized at the end of the project lifecycle in Deliverable D5.5, when the final results and assets will be well known and available.

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Executive Summary

Deliverable D5.3 aims at providing an overview of the market segments interested and potentially addressable by the technical assets that CHARITY is going to produce. In addition, it offers an intermediate update of the high-level strategies and envisioned drivers that the CHARITY partners consider relevant for exploiting the project results at benefit of their business goals.

Deliverable D5.3 presents a transitional view of both the observed evolution of the main target markets for CHARITY results, and the strategic guidelines showing how the project's assets can be exploited for the sake each partner's business goals. These exploitation plans, as well as the market perspective, will be refined and completed with the second final revision of the current report (D5.5, planned at month 36, or 42 if the project lifetime is extended as from currently evaluated amendment). Such transitional state of the exposed analysis is in line with the global project roadmap: at the time the present deliverable is released, in fact, the project has completed its first architectural analysis, and is in the middle of implementing the first version of its technology components. Accordingly, what we present here is an estimation of what the actual exploitation might be making some initial assumptions.

The final deliverable – D5.5 – will capitalize on the definitive version of the project technical implementation, as well as on the evaluation that will take place on the CHARITY integrated prototypes. Ultimately, D5.5 will also take advantage of the interactions with key stakeholders, which the pandemic crisis dramatically hindered in the first 18 months, and that is expected to consistently happen in the forthcoming project phase. In this deliverable we also briefly present an overview of the way we plan to approach this stakeholder interaction, to capture as many as possible valuable inputs and increasing the innovation value of CHARITY.

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Abbreviations

5G-PPP	5G Infrastructure Public Private Partnership
AAA	Authentication, Authorization, Accounting
AAE	Adversarial Autoencoder
AB	Advisory Board
AR	Augmented Reality
CSP	Communications Service Providers
DoA	Description of Action
GDPR	General Data Protection Regulation
HPC Lab	High Performance Computing Laboratory
MR	Mixed Reality
SECaaS	Security as a service
SME	Small Medium Enterprise
VC Lab	Visual Computing Laboratory
VNFs	Virtualized Network Functions
VR	Virtual Reality
XR	Extended Reality

1 MARKET SURVEY

1.1 General market overview

In the following sections, we provide an overview of the different market sectors potentially addressable by CHARITY. In particular, we throw a look at the multiple market domains targeted by XR services and applications, focusing on the areas interested by the use cases that we will implement and evaluate within the project. In more of these cases, the market analysis did not undergo significant changes with respect to the situation assessed at the time when CHARITY was conceived, as reported in the DoA. In other cases, there have been some updates that we tried to catch and report in the sections hereafter.

1.1.1 XR applications & services market

1.1.1.1 Real-time holographic applications market

Holography in general is a research field established by Dennis Gabor (1900-1979), which possibly started to attract overall public attention in 1971 as he received the Nobel prize in physics. Until today the field is still under intensive research to enable perspective real-time holographic applications in the future. In the last 10 years, a quite different and much simpler technique based on projection to visualize objects, persons or information in space was developed. Today nearly all variants independent of the technology used (true holography or projection) are unfortunately summarized under the general term “holographic” or “Holography”. Therefore, it is not easy to find out which technology is used for a certain holographic application. Basically, it can be differentiated such that projections are typically flat 2D planes projected onto some medium like glass or foils, while true holograms (cf. Electro holography) are using RGB lasers and are based on the diffraction of light. Electro-holograms mimic natural viewing and thus always provide large 3D depth in space including ability to naturally focus with your eyes. Another segment is the 3D stereo technology typically used in cinemas, VR / AR glasses or TVs/monitors, here also the term holographic is often misused. But this 3D stereo segment will not be considered here. Basically, the markets for Holographic applications could be split up into these two categories, Pseudo and True Holographic.

Pseudo holography is already in the market, mostly it is used for signage/advertising, for effects on events or concerts. Some devices are already sold to consumers / customers but this is not comparable to classic markets like monitors, projectors or TVs. The big advantage of this technology is scalability to any size and it is visible to any number of persons. The Charity Use Case 1 “Real-time Holographic applications” including holographic concerts and meetings will be based on this type of technology.

Products based on true holography (real-time) are still not on the market. The technological and computational requirements for such devices are extremely demanding but are on the path for first products in 2-3 years. The advantage of 3D holography is to enable visualization of 3D content/objects/scenes exactly the same way as it would be perceived when this would be a physical object. Charity use case Holographic Assistant will be based on true 3D Holography.

In general, multiple market research experts forecast a CAGR for holographic display applications ranging from 23,8% to 29,1% in the next 8-10 years - cf. Figure 1(Allied Market Research, Mordor Intelligence, Emgen Research).

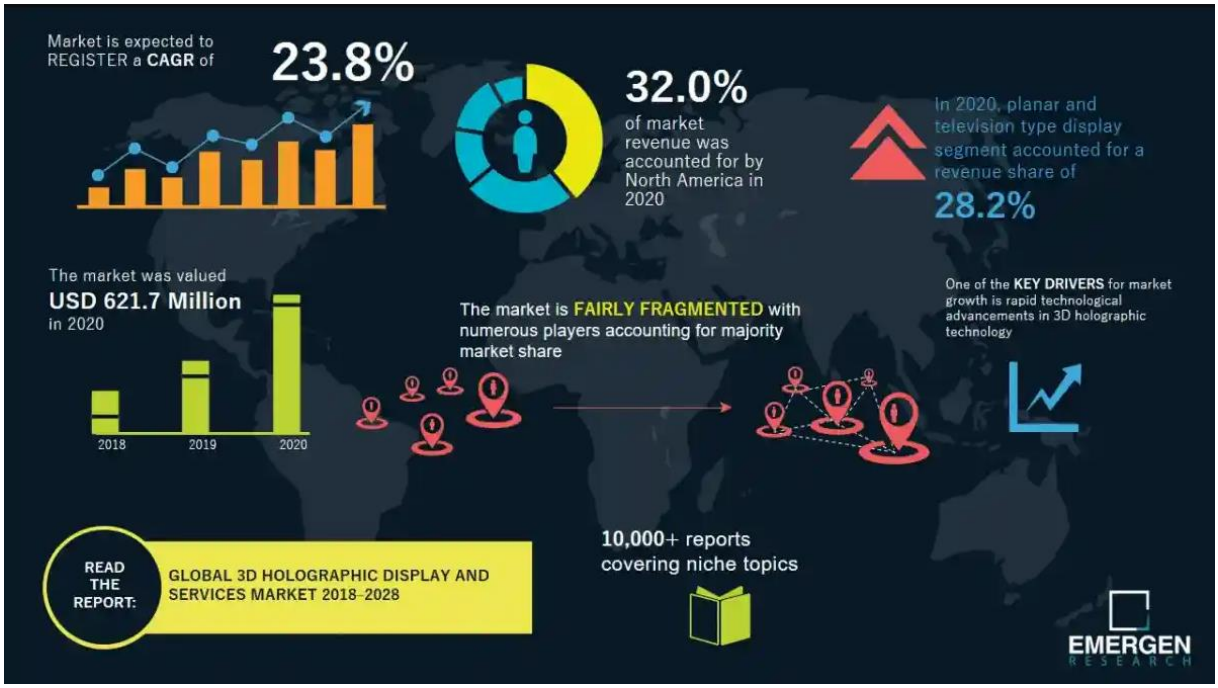

Figure 1: Overview of market forecast for holographic display market from different market experts[1][2][3]

A strong demand for real-time true holographic applications can be seen especially in the field of video communication, beside others like 3D gaming and professional 3D applications. Since the beginning of the Covid-19 pandemic, an enormous growth of telepresence / video communication markets was registered due to the requirement of home office, home schooling etc. It is obvious that true holographic 3D video conferencing devices would even more increase acceptance and user experience since it is much closer to a real face to face meeting than common 2D video on a flat screen. Other holographic 3D applications will be working or playing in true 3D as everyone is used to interact with 3D object all the time in real life.

[1] Allied Market Research https://www.alliedmarketresearch.com/holographic-display-market-A12501

[2] Mordor Intelligence https://www.mordorintelligence.com/industry-reports/holographic-display-market

[3] Emgen Research https://www.emergenresearch.com/industry-report/3d-holographic-display-and-services-market https://www.emergenresearch.com/blog/top-10-companies-offering-3d-holographic-display-and-services

Holographic devices present in the Romanian market

Devices overview.

There are several devices that are considered “holographic devices” on the Romanian market. One type uses a fast rotating led bar (like a fan) that creates the impression of a free-floating image

Figure 2: Holographic device

The resulting effect can be assessed here: https://www.youtube.com/watch?v=VVt-eN90mx4. There are several companies that sell or offer to rent this type of low-cost devices. They are sold for around 700 euro a piece, and several can be clustered to cover larger areas.

Another type uses the reflection on a half mirror, the so called “Pepper Ghost effect” This is the type that we, at Holo3d, are using.

Our devices range in size and functionality. Some have a single sided projection, like the POP3:

Figure 3: POP3 holographic device

The effect can be assessed here: https://www.youtube.com/watch?v=3_NRgRNu1-w

Other devices have the projection on three sides, like the Dreamoc HD3:

Figure 4: Dreamoc HD3

A video of which can be seen here: https://www.youtube.com/watch?v=I1kllyvDpug

Some devices, like the Dreamoc Diamond, or XL, or Scandinavia XXL, are very massive and can project large size holographic content:

Figure 5: Dreamoc DIAMOND by Holograma3D

A video of the large devices here: https://www.youtube.com/watch?v=z9y28DvOXF0&t=1s

https://www.youtube.com/watch?v=otcVFssUVM4

For real size holographic content (like concerts) we use a special setup:

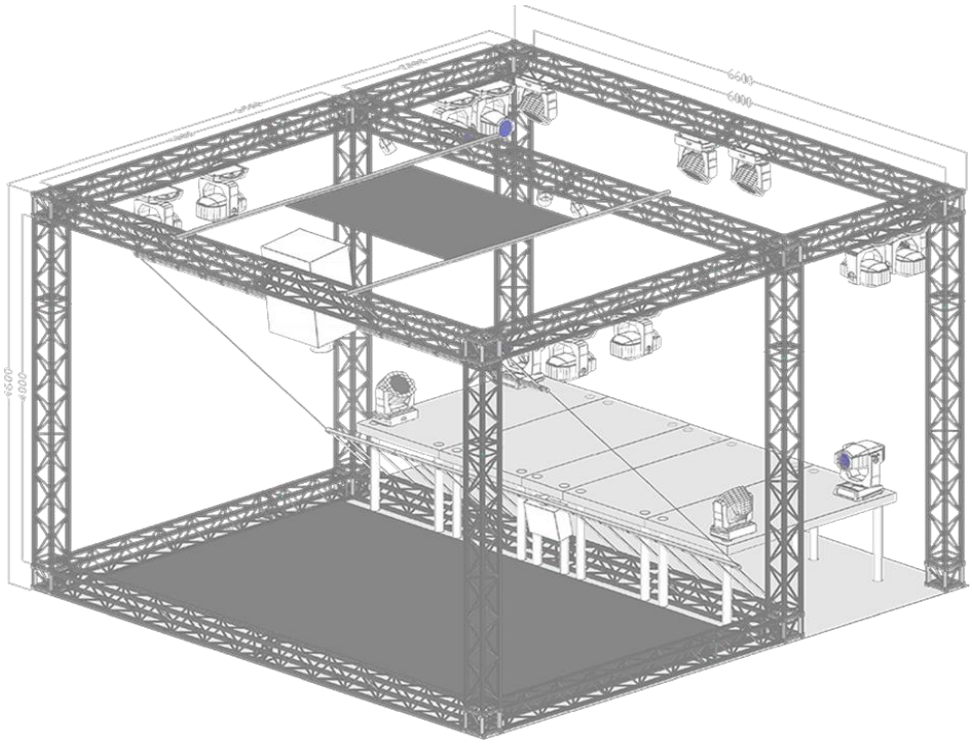

Figure 6: Holographic content

This works like shown in this video: https://www.youtube.com/watch?v=1RDdrDOJv8I&t=2s

A short demo is here: https://www.youtube.com/watch?v=09Md5oqtUOQ&t=15s

1.1.1.2 Immersive virtual experience applications market

The Virtual Reality (VR) marketplace has grown significantly over the last period, in both the consumer and the enterprise spaces. As per the Grand View Research [12], the global virtual reality market size, valued at USD 10.32 billion in 2019, is expected to grow from 2020 to 2027 by a CAGR of 21.6%. The Mixed Reality (XR) sector currently counts 4580 companies [8] and more than 171 million VR users worldwide [9]. The technological innovations in 5G technology and the adoption of immersive technologies can have a tremendous impact on the market growth in the forthcoming years, a fact that it is depicted in Fortune Business Insights forecast who foresees that the global virtual reality market size is expected to reach USD 84.09 billion by 2028 [11], exhibiting a CAGR of 44.8% during the forecast period.

Although the current bulk of that growth has come from the healthcare sector, reaching USD 1.2 billion in 2024 [10], as the XR market matures, the enormous value that VR may bring to many other areas, especially in the field of virtual training and collaboration, is gradually realized. The virtual reality collaboration and training platforms market will likely witness the fastest growth over the forecast period (2020-2027) as more businesses incorporate XR technologies into their communication strategies.

However, certain growth predictions have not yet materialised. While VR hardware has now reached human eye resolution at an affordable price, headsets are still rarely used in professional or leisure applications. Although hardware is a limiting factor for VR mainstream adoption, the main problem lies in the costly and time-consuming VR software authoring process.

Nowadays, global pandemic has triggered the utilization of technological means by companies that are active in automotive, manufacturing, aerospace and defence, education, and other industries, to meet their business needs. Virtual simulators assist in the remote collaborative design and planning of products. Furthermore, VR is also gaining popularity in the education/training sector. To this end, virtual technology is being utilized by people all over the world to support/improve their health and well-being, entertainment, live events, virtual conferences, and meetings, within a safer, Covid-free environment. Additionally, many industries are heavily investing in virtual training solutions. In the automotive sector virtual training modules for new joiners aim to minimize accidents. Moreover, virtual training solutions are being used across the healthcare business, where healthcare practitioners improve their skills and precision on medical operations and eliminate errors.

Finally, Facebook company's metaverse vision of becoming the successor to social presence in the digital era and eventually realize the full social potential, highlight the need to improve VR/AR, not only for entertainment and social experiences, but also for learning and training in several domains, i.e., healthcare, automotive etc.

VR Virtual Tours market

Virtual reality tours are already in the market for some years. A virtual reality tour stands by a mix of 360º content, 3D entities with interaction and 2D user interfaces. Usually, a virtual tour is based on web, but can also become an installable app on mobile. It can be considered a complete product, as it can behave like a website, an immersive experience for learning, tourism or other industry vertical and also an e-commerce shop. The present market of virtual tour creator software is growing since this type of technology has become widely adopted. Software like, Matterport, 3D Vista, Cloudpano are just a few of the direct competitors of Cyango Cloud Studio. This software are mostly using the SaaS business model based on subscription payment.

Table 1: Software tools

	Cyango	Matterport	3D Vista	Cloudpano	EyeSpy360	Klapty	isStaging
Cloud Platform	😃	😃		😃	😃	😃	😃
Video Editor with Timeline	😃						
Acessiblity Tools	😃	😣	😣				
WebXR	😃	😃	😃	😃			😃
Multiresolution and Live Streaming	😃		😃				
Use any camera	😃		😃	😃	😃	😃	😃
Dolly House 3D Tours		😃					
White Label	😃		😃	😃			

As you can notice in above table, the video editor on cloud is the only feature that can disrupt this market, as this is a requested feature from the customers. The video editor on the cloud will allow the user to skip the extra third-party software subscription they need to pay. The usual workflow of a virtual tour creation is: start recording with a 360 camera, stich the 360 videos on the proprietary software, then edit the videos on paid software like Adobe Premiere, then upload the final videos to Cyango Cloud Editor. What this video editor feature will do is to remove the need of having more paid software like Adobe for this specific 360 video editing.

VR medical training market

VR has been successfully used in the field of medical training in multiple cases. Aiming to improve medical training for surgeons, the Johnson & Johnson Institute worked with Osso VR to develop immersive training for medical operations. The outcomes of the virtual training showed a 230% increase in surgical performance.

VR experiential training is based on a mistake-driven learning approach, allowing doctors to learn the curriculum in a risk-free environment. Using this type of learning solution, trainees may perform as many training sessions as required in the virtual world, allowing erroneous handlings at no cost, compared to the cost of human error in reality.

The direct competitors in medical training are custom VR content providers or software and hardware aggregators, based on existing 3D game engines, such as Unity3D and Unreal engine. To the best of our knowledge, these solutions are full-stack monolithic applications that do not provide any novel technology intellectual property (IP) for enhanced realism or suitable-for-prototyping SDKs. The figure below depicts the direct competitors (OssoVR, Fundamental Surgery, PrecisionOS, osGenic, ImmersiveTouch, SImForHealth) to ORAMA, along with core features of the multi-user VR training platform they provide.

Product Features	ossoVR	Fundamental Surgery	PrecisionOS	osGenic	ImmersiveTouch	SImForHealth	ORamaVR
Low-cost VR	●		●		●	●	●
Gamification	●	●	●	●		●	●
Proprietary user performance metrics	●	●	●		●	●	●
Proprietary VR scene description format							●
Proprietary virtual human simulation							●
Multiplayer, networked collaboration engine	●* 1 active, others passive	●* 1 active, others passive	●* 1 active, others passive				● all active
Haptic Feedback		●		●	●		●
Platform SDK for rapid prototyping encompassing all features above							●

Figure 7: Comparison of ORAMA platform features to those of direct competitors

Indirect competitors in this field are general simulation-based medical training companies that develop custom hardware for robotic-based simulators, mainly for minimal invasive operations. Such solutions require fairly expensive haptic devices and have limited usage.

1.1.1.3 Mixed Reality Interactive Applications Market

Mixed Reality is characterized by a mix of VR and AR technologies and, crucially, it enables interaction between physical and digital objects. It does not remove users completely from the real world as with VR and goes beyond AR in layering content on real world views in that it enables interaction between physical and digital objects – manipulation of digital objects in our field of view can drive changes to the physical environment and vice versa. Such functionality reaches well beyond VR and AR and we need to be careful of Mixed Reality market projections that conflate it with VR and AR. In [1], the authors consider MR to be synonymous with Extended Reality ("the significant technologies which are earning a lot of market attention are Virtual Reality (VR), Augmented Reality (AR), and Extended Reality, i.e., Mixed Reality (MR)") while elsewhere drawing a distinction between AR and MR. Their market projections for Mixed Reality must be questioned (valued the global MR market to be $376.1 million in 2020 with an expectation for this to grow by an order of magnitude by 2026 to $3,915.6 million) and we can see significant differences with other reports such as [2] which values the global MR market at less than half this figure at $155.85 million in 2020 with a forecast for this to grow to

$3417.64 Million in 2029. Similar disparities are evident with [3] where they estimated the MR market was already worth $1054.3 m in 2017 and with [4] who estimate an enormous CAGR of 72% a year and thus rapidly escalating market size estimates. There appears to be a misunderstanding amongst market observers akin to estimating the market for fruit baskets by adding together all the markets for individual fruits while arguing that a basket with a single type of fruit is still a fruit basket.

For comparison, we show the four mentioned market size and growth estimates side by side below.

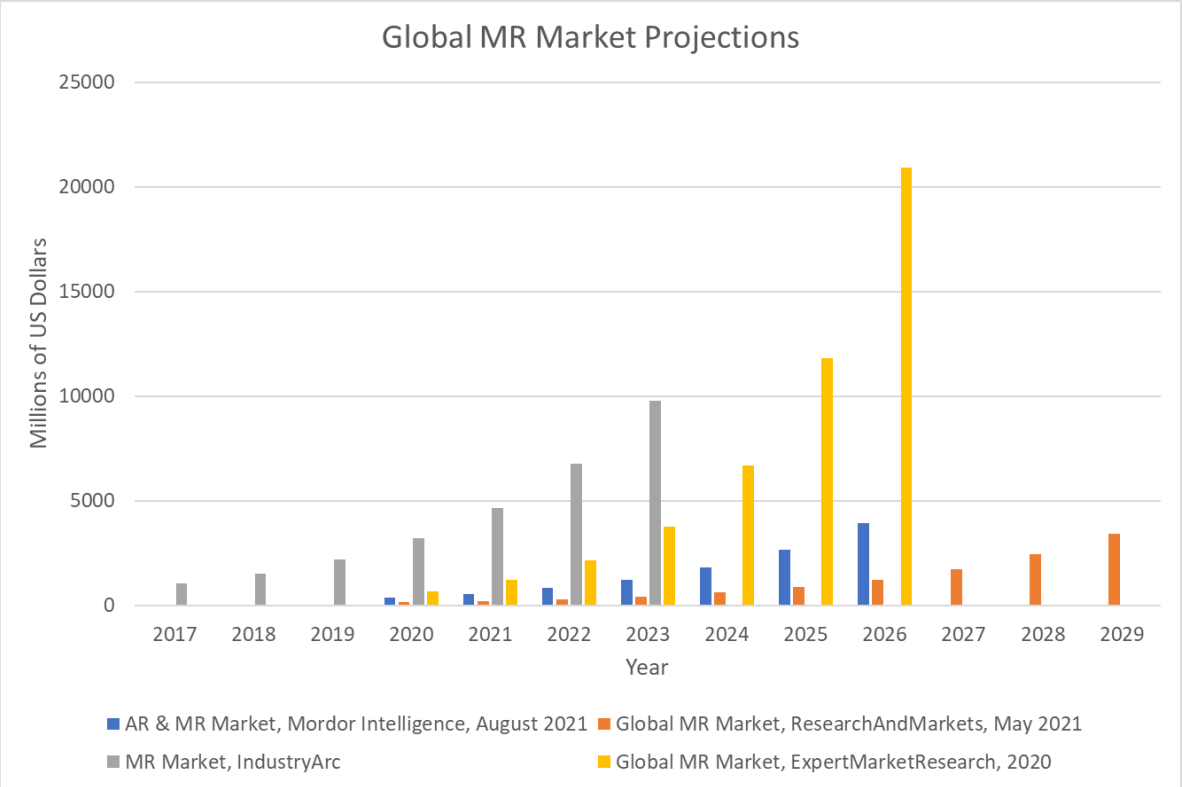

Figure 8: MR Market

While all observers predict significant growth in the Mixed Reality marketplace, it seems they do not all agree on what the marketplace actually is. Growth and advances in AR providing the capability to convincingly overlay virtual objects on physical surroundings are essential for Mixed Reality. It is instructive to look at investment and activity patterns amongst key industry players in this space

Facebook are racing to bring its first generation of AR glasses, Project Nazare, to market in 2024 with follow-up plans already in place for subsequent generations. While Mixed Reality is firmly within Facebook's sights, there are a host of other challenges involving miniaturization, haptics, photo-realistic avatars, etc. that are also in the mix. Facebook are all in however, and the scale of their commitment is revealed in their $10 billion spend on AR & VR research in 2021 [5]. There is a lot of activity from other players with deep pockets including MagicLeap which received a new boost of $500 million in funding in 2021 to continue progressing with its enterprise AR glasses [6]; Google's well-funded Project Iris with cloud supported AR glasses is slated for 2024 [7]; Apple's foray into AR glasses is rumoured to hit the shelves in 2023 [8]; Microsoft plans for the future of the Hololens remains the subject of much speculation but their interest in Mixed Reality does not appear to have dampened with the rollout of Microsoft Mesh as a fabric on which to build and deploy mixed reality applications.

Although at present the level of AR and VR gaming market value growth appears to be quite slow it is predicted [8] that the growth momentum of the market will accelerate during the forecast period. The industry as a whole, with the global VR market size projected to increase from less than five billion U.S. dollars in 2021 to more than 12 billion U.S. dollars by 2024 and then significantly accelerate reaching

between $60B and $70B. Some predictions are more optimistic [9], claiming that the pace of growth will be so high that the market value of this branch of the gaming industry will reach even up to $160B. AR gaming market growth seems to be strongly related to the market success of the announced AR dedicated devices mentioned above, AR glasses in particular.

1.1.2 Edge2cloud infrastructure services market

The introduction of the edge computing concept some years ago quickly brought the rise of a market segment dedicated to the edge infrastructure. New devices, and related software management solutions, were introduced with proper features to satisfy the requirements of an edge infrastructure layer, starting from a lightweight footprint, reduced power consumption, and suitability to be deployed near to the field layer, e.g. user terminals, IoT devices, sensor networks and so forth. An example of similar equipment was the HPE Edgeline servers, designed to be deployed in factory environments, closely connected to the production devices layer.

Over the years, the edge computing market has experienced impressive growth. A very recent report [12] forecasts a USD 61,14 billion size for the global edge computing market by 2028, spread more or less equally across multiple vertical industries. An outstanding factor underpinning this growth is given by the development of 5G mobile network infrastructures, whose highly spatially dense characterization offers a huge number of physical facilities potentially able to host a piece of edge computing infrastructure (currently dubbed as *edge data centers*), in turn increasing the closeness of edge layer to the field devices.

Another key enabler is the spreading of IoT networks, in different contexts spanning from Industrial IoT to smart cities, making edge computing advantages become even more tangible. Finally, there is the improvement of edge devices horsepower, making them able in particular to host and run Artificial Intelligence/Machine Learning algorithms. This feature allows at least an initial local processing of collected data flows, reducing the amount of traffic reaching out back-end and traditional cloud servers, with a related improvement of processing performance, latency reduction and optimization of available network bandwidth. Local execution of AI algorithms can squeeze the timing for certain automated decision down to the order of milliseconds. Additional advantages coming from this improved processing power include the reduction of security perimeter, avoiding to expose large data blocks to crossing unsecure transport network chunks.

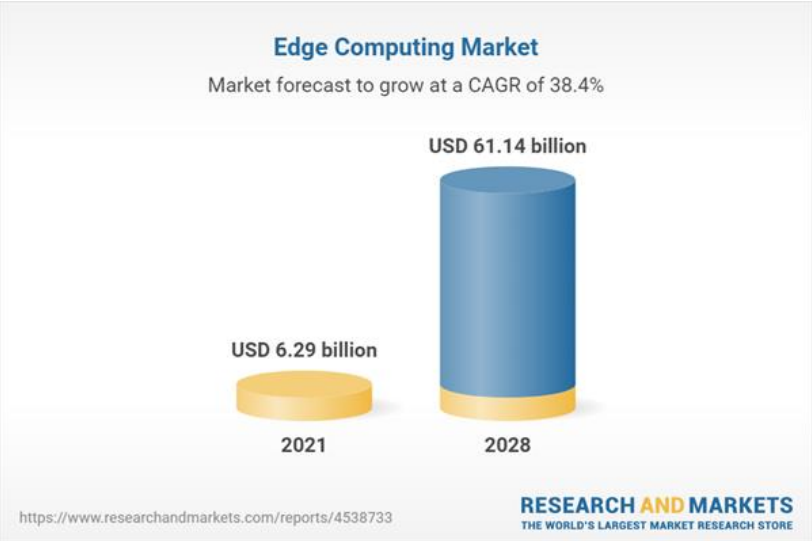

Figure 9: Edge computing market

It is obvious that the XR applications addressed by CHARITY can take great advantage from being deployed even into the edge. Indeed, the ramping up success of XR applications is identified as one of the most responsible for the growth of edge computing infrastructure market.

Nevertheless, in the CHARITY vision the real breakthrough is not coming from a full edge deployment of XR applications. What CHARITY envision as optimal target is a renowned design of XR applications as cloud-native, microservice based services, with the support of the technology that CHARITY itself will provide (slice blueprint definition, resource orchestration, optimized deployment and lifecycle management). This redefinition of XR application model can enable a new deployment scheme, where different composing microservices are deployed and executed in different back-end clouds and/or edge infrastructure devices, according to their specific performance requirements and constraints, backed by a smart management of the network fabric interconnecting the different microservices.

Hence, CHARITY looks at the edge-to-cloud continuum space, pursuing an optimized model of application deployment, where the XR applications undergo a redesign process (duly supported by CHARITY technology enablers, like the application management framework) aimed at making them more cloud-enabled, and distributed in the best possible way over cloud and edge federated infrastructures. Hence, the cloud service market itself can have a boost from the project results, fostering more XR service providers to deploy part of their applications into the "traditional" cloud, including the public cloud, thanks to the improvement in service quality assurance that CHARITY can unleash. The amount on this positive impact on the cloud services market is not still quantifiable, however it might be particularly interesting for medium size CSPs, that might more easily offer a service portfolio specifically tailored to this emerging class of applications, and be the first ones to exploit this novelty, acquiring a market niche where they can compete with the bigger providers.

A hybrid, multi-cloud approach further driving cloud adoption

Hybrid cloud is essentially a combination of on-premise, private cloud and public cloud. It is a model that has been gathering pace in recent years as organisations attempt to run some workloads in-house with the ability to burst into the public cloud when demand dictates. As an extension of this, multi-cloud computing is defined by the use of multiple public cloud providers, allowing customers to pick and choose the services they actually need in a more cost-efficient way. However, the two models are not mutually exclusive and organisations are becoming increasingly capable of combining both to take advantage of different features and cost models available from different vendors. In this way, a hybrid, multi-cloud approach is an inevitability, allowing organisation to compare and choose from such a wide array of IaaS and PaaS solutions. It would be not very realistic to assume that an organisation could remain single-vendor over the long-term. It is also not surprising that a hybrid, multi-cloud approach is helping to drive even greater cloud adoption and industry growth in general. Cloud Service Providers (CSPs) are generally very supportive, since they are the direct beneficiaries of this growth. Driven by customer demand, CSPs are beginning to roll out the necessary functionality and tools to support workloads that can run across multiple clouds. There are also a growing number of third-party, cloud agnostic services and tools being developed to facilitate such an approach.

According to the Hashicorp 'State of Cloud Strategy Survey' [13], 76% of respondents stated that they already work with multi-cloud environments. The survey also shows that this is expected to rise to 86% within the next two years. In terms of multi-cloud adoption, this seems to be currently more popular with larger enterprises (90% of respondents surveyed were from enterprises with 5000+ employees) with large IT departments. However, there is substantial growth predicted to be driven by smaller organisation too. Among the most cited drivers "digital transformation" was considered the most important factor for multi-cloud adoption, followed closely by vendor lock-in and cost. Although multi-cloud deployments currently still favour the big three hyperscalers (AWS, Azure, Google Cloud), there are significant gains to be made by smaller CSPs since the approach promotes interoperability by default, regardless of the cloud technology employed. This is supported by the growing number of open-source software tools for automating multi-cloud functions, which according to oper 50% of respondents are preferred (provisioning: 67%, application deployment: 61%, and networking: 58%). Security dropped below half at 48% with 52% of respondents preferring commercial services. One of the most popular tools and services is Hashicorp's own Terraform, which is based on an open-source provisioning and orchestration platform, while Kubernetes containerisation and the Github deployment platform are also often cited.

The main blocker for achieving a robust multi-cloud setup were security complexity (47% of respondents), cost uncertainty (51% of respondents) and perhaps not surprisingly for smaller organisations, a lack of in-house expertise (41% of respondents). This last point was backed up by 57% of respondents citing skill shortages as a major contributing factor hindering their ability to put multi-cloud environments into production.

In summary, the survey conducted by Hashicorp highlights the growing popularity of a multi-cloud approach with 86% or respondents expecting to adopt the approach over the next two years.

1.2 CHARITY positioning

1.2.1 Innovation value proposition

Connecting to what described above in the market analysis section, the CHARITY innovation value is at largest extent focused on its key target segment, i.e. the domain of advanced, next-generation AR/VR/holographic applications and services that are expected to take the major benefit from the technical results that the project aims to achieve. The innovation impact of CHARITY has nevertheless the potential to also hit other business segments, like the market of infrastructure services with a growing need of specific advanced services addressing this kind of applications.

The innovation value of CHARITY is in principle looking at some major drivers, expected to enable a significant step forward in the quality of experience that a wide set of XR services, embodied by the multiple CHARITY use cases, can deliver to their end users and customers. We can, at high level, consider such drivers as:

- improving the effectiveness and efficiency of resource orchestration and allocation during the deployment of XR applications; here the innovation is sought in two different paths:
    - supporting the applications themselves to be modernized according to a microservices, slice-based modelling; this innovation branch is expected to deeply impact the XR application market at multiple levels, facilitating the construction of modernized workloads able to run on an optimized virtual infrastructure and allowing XR developers to focus only on the application functionalities, letting them rid from the burden of monitoring and optimizing the application/service performance; furthermore, this innovation will facilitate a modularization of the XR applications, ultimately improving their costs of application maintenance and upgrading (thanks to the selective development enabled by a microservice-based modelling); the evaluation activities will allow to find out which specific XR application categories can take the maximum benefit from this evolved structuring
    - developing advanced scheduling algorithms, able to find the optimal resource allocation for the application composing blocks across multiple domains including edge resources as well as back-end cloud points of presence; this type of innovation might have a significant potential impact on technology vendors able to capitalize on the core components of the CHARITY platform, selling their technology to infrastructure service providers interested to host new-generation XR applications onto their premises;
- developing an environment where the XR application is controlled over its whole lifecycle, capturing and possibly anticipating degradations of quality, and automatically intervening through a closed-loop control mechanism, able to reallocate the application components and/or to adapt the configuration and horsepower of the physical nodes hosting such components; also this innovation vector can be impactful on both the XR application markets, making the applications and services more appealing due to the extreme achievable quality of service, and to the infrastructure service market, which might integrate the specific capabilities of CHARITY into their own service platforms. This kind of innovation allows cloud service providers as well as technology vendors to offer advanced environments specialized for

hosting and running XR/holographic workloads, and also potentially enabling a business segment of "federated" infrastructure providers, willing to join their resources into a unique service platform for XR applications/services. This exploitation driver has a potential baseline to look at in the emerging NFV infrastructure market, driven by similar principles, as well as in the alike research efforts ongoing in sibling projects like ACCORDION [10]

- providing specific pieces of enabling technologies, potentially exploitable by multiple XR applications, in a highly composable model where such enablers can be interchangeable depending upon the given requirements of the considered application deployment. This innovation can potentially foster the growth of a new, additional market niche, open to advanced technology vendors offering highly specialized components for extreme performance applications, like some of the assets that will be described hereafter.

To satisfy these general innovation objectives, CHARITY is investigating and implementing a number of specific technology assets, that will also represent its actual collection of exploitable items. After the project's completion, each partner will take the most beneficial assets to its own business strategy and objectives, looking after their upgrading to a higher Technology Readiness Level. Such strategic guidelines are outlined, at their current preliminary stage, in the section 2 below.

At the current project lifecycle stage, also not overlooking the negative impacts that the pandemic had on CHARITY, recommending to pursue a project lifetime extension, the key activities behind the definition of a business framework are still not close enough to an initial useful stage of completion. The technical development phase 1 is still in progress, so, although we have a design specification and an architectural definition, the detail and even the exact outlining of the exploitable assets is still susceptible to be amended, after the feedbacks that will come from the integration and testing phases. Consequently, the information that we can provide at the time the current report is delivered have to be considered as an initial, preliminary level, not recommending to draw extensive evaluations and investigations on the possible business evolutions that CHARITY will foster. Furthermore, the same pandemic context prevented at a very large extent CHARITY from implementing the outreach actions towards its key stakeholder communities (outlined in 1.2.3 below, causing the lack of another key set of feedbacks fundamental to properly envision the business perspective.

Bottom line, in the current report we describe what we can envision at the current technical development stage for the exploitable assets that the project might generate, and sketch a summary vision of how they might modify the business scenario. Also, the individual exploitation plans reflect this temporary state of the underlying information, remaining bound to a recall of the exploitation strategies drafted in the DoA itself, with the proper updates where these occurred in the last couple of years for the respective reference markets and/or business offering portfolios. In the second and final version of this report (D5.5, planned at the very end of the project) these sections will be duly deepened, connecting the analysis to the actual available results and inputs coming from all the external outreach activities.

Impact for SMEs

Even when taking into account the above outlined early stage of project technical development, there is nonetheless a consideration that we feel confident enough to anticipate: much if not all of the innovation that CHARITY will produce, has the potential to result highly beneficial for SMEs (Small-Medium Enterprises), thus meeting one of the outstanding strategic objectives seized by Horizon 2020 projects, and also one of the recommendations that the project received after its first technical review meeting. In fact, as we can envision from the summary overview of innovation drivers and expected assets, key beneficiaries of CHARITY results are classes of stakeholders many of which are widely represented in the SME arena. The first group of stakeholders in the radar of these benefits are the XR application/service vendors and developers, serving markets with an outstanding expansion potential, as outlined in section 1.1, but to date still in a phase where many of these makers are niche segments, and the average size of vendors is typically the one of small-medium Companies.

How can this ambition be met? A key concept underpinned by CHARITY is indeed to reduce at a minimum the effort for XR/holographic application vendors to cope with all the elements not directly

tied to their application core functionalities, like resource allocation, infrastructure monitoring, application/service automated lifecycle management for tight SLA assurance, and so forth. Getting rid from these constraints allows SMEs to concentrate their resources on XR functionalities and core application development, drastically reducing their development and testing costs, speeding up their time to market as well as their average service upgrade or patching time. The Application Management Framework is a key asset at this purpose, since it provides XR developers with an environment leading them to design or re-design their application along with the cloud-native paradigm, facilitating the definition of slice blueprints through a guided editing interface, in a word decoupling them from the issues not providing real added value to the core functionality offered to their end users. But the whole CHARITY platform completes this isolation for SMEs from non-core tasks, allowing them to more easily define and control how their deployment will happen, in a similar way to the improvement offered by a "traditional" public or private cloud deployment paradigm.

The point above is probably the most immediate, nevertheless it is not the only way how CHARITY can have a positive impact on SMEs. Another market that CHARITY can help to open up is in fact the one of XR service enablers. In CHARITY, SMEs are represented not only by more use case partners, but also by some key partners developing the core CHARITY asset. The niche of developing specialized technology enablers supporting the CHARITY deployment model, and offering highly performant and specialized capabilities to specific XR application segments, is another market niche particularly well fitting the SME community.

Finally, the particular type of deployment that CHARITY can enable, distributed across a heterogeneous edge-to-cloud layer covered by an ensemble of potentially federated infrastructures, is the best fit to support a market expansion for small-medium infrastructure service providers. In fact, with the CHARITY model even lower-scale, lower-horsepower infrastructure pieces can more easily participate to the deployment of an XR service/application, thanks to the distributed model where different slices can be served by different scale infrastructures under the overseeing of the whole CHARITY platform orchestration.

In conclusion, notwithstanding being in an interim phase of the project yet, where it's still not possible to give an exact definition of its business model, we believe that a positive impact on access to market for SMEs can be already asserted with a high degree of confidence.

1.2.2 Outline of exploitable assets

As stated above, the exploitation of CHARITY will be actuated capitalizing on a number of technical assets that the project is slated to develop and prototype, that can have their own impact on markets and business interests of partners, as self-standing components as well as integrated into pre-existing legacy products and services. The extensive detail of exploitable assets will be available at a later project stage, nevertheless the current advancement state allows us to outline the candidate assets. They can be split in two different groups:

- core technology components of the CHARITY platform: these are mostly developed and provided by the work done in WP2
- enabling technology blocks: these are the elements dubbed "service enablers" in the CHARITY architectural specification, and are mostly produced by the research and development activity ongoing in WP3

We go here through a summary outline of the possible assets envisioned at this stage in the two categories.

Platform components

Cross-domain resource orchestration:

One of CHARITY's aim is to provide a cloud platform for XR services. Due to the stringent requirements (high computation and low latency) of XR services, designing them as micro-services and deploying them over a cloud-edge continuum is primordial for efficiency. The proposed platform shall be able to

perform an optimal domain selection that satisfies the SLA of each XR service. Given the nature of XR services, such a platform shall be also able to accommodate all of container load, VM load and even a mixture of the two. This is due to the fact that some part of XR service, such as graphics engines, are not containerized yet.

Distributed service orchestration and resource scheduling:

Given the nature of the proposed platform, the different domains have different purposes and may belong to different entities, thus they may need different orchestration mechanisms. Therefore, the orchestration framework is distributed over all the domains. One approach that we are following in CHARITY is to have ML and especially RL agents acting as scheduling mechanisms inside each domain (or Kubernetes Cluster). Also, a specific simulator is being developed that would help in jump starting the learning of RL agents. This simulator would train RL agents to find good policies before letting them refine them in real environment.

Cross-domain communication and dynamic routing mechanisms:

To stitch among domains, a networking fabric is needed. In CHARITY, this is done by a WIM component that can connect the micro-services across different domains. The dynamic routing mechanism is able to re-route traffic in a smart fashion in order to take advantage of the current status of the platform and needs of the XR service. Indeed, different paths have different latencies and different costs, the dynamic routing mechanism would ensure that current path satisfies the SLA (latency and reliability) while minimizing the costs.

Computation and Network resource utilization prediction and Service migration triggers:

Resource utilization prediction is needed in the context of CHARITY in order to perform informed scheduling and service migration decisions. Currently, some ML based algorithms have been proposed in this vein for the prediction of both computation and network utilization. CHARITY also aims to devise some specific triggers for the migration of XR services. Leveraging prediction mechanisms and composing adapted triggers would ensure preserving the SLA of XR services by taking pro-active measures.

XR blueprint definition:

CHARITY proposes a framework for XR applications blueprint definition, which addresses two main requirements: 1) providing a user-friendly tool to XR application developers to easily define their services by composition of micro-services and definition of their communication paths; 2) defining a flexible, standards-based representation model for the XR services that can be understood by orchestration services to deploy and manage the life-cycle of the XR application.

As for the first requirement, we are developing a Blueprint Editor, which is part of a web portal based on a micro-frontend architecture pattern. This modern design allows for the highest degree of flexibility and extensibility, allowing different development teams to add features and services in full autonomy. Regarding the XR application blueprint model, it is based on the TOSCA specification, a very well-recognized standard, which has been properly extended and customized to define the characteristics specific to the Charity XR applications domain.

Security aspects:

CHARITY explores three security aspects for accommodating XR services. The first is to expose Intel-SGX technology to offer secure enclaves where code can be securely executed and where sensitive data can be loaded. This would allow XR developers the ability to create isolated enclave environments in the nodes between each container application. The main benefit of this is to execute code and protect data inside a trusted execution environment to help prevent software attacks, even when the application, the OS or the BIOS has been compromised. This can be done by enabling Intel-SGX technology at the infrastructure level when provisioning a server and selecting the enclave size. Several SDKs are available to enable XR developers to create the two necessary components; an untrusted

component (the host) and a trusted component (the enclave). The second is to obfuscate both physical and logical network topologies from attackers. Finally, the third is to secure the platform and XR services by providing a security as a service (SECaaS) model for dynamically launching different security functions, including a network anomaly detection and mitigation mechanism specifically tailored to cloud-based environments for transparently detect cyber-attacks and enforce security policies accordingly.

CI/CD pipeline:

One final innovation objective is to provide some kind of CI/CD pipeline for XR services. This pipeline should be used by XR developers for integration and testing purposes, to ensure a fast and smooth experience for XR providers when defining and later deploying their services. Given the complexity of the deployment scenarios, CI/CD pipelines might potentially help developers by performing validation steps, verification of proper packaging of artefacts, static security analysis of images. For full cloud native XR applications, small-sized testbeds might be setup to allow developers to specify and run automated integration testing steps. Since the definition of a CI/CD environment has a strong dependence upon the implementation details of the CHARITY platform, it is not part of the first development cycle, and will be tackled only at a later stage.

XR enablers

Monitoring subsystem

CHARITY will develop a dedicated monitoring architecture, specifically tailored on the requirements elicited by the CHARITY use cases, as representative of a wide range of XR/holographic applications. The monitoring subsystem will support multi-domain/multi-cloud deployments, addressing the technology variance existing in CHARITY. The monitoring system will support the decision made by the orchestrator and will make the running XR applications not only duly reactive to changes of conditions, but even possibly able to prevent situations of performance degrade.

Edge storage subsystem

Deploying XR applications with the extreme performance levels requested by CHARITY demands the presence of an optimized set of storage services, able to meet such high requirements. The CHARITY subsystem, dubbed CHARITY Edge Service (CHES), addresses storage and retrieval of data, data movements, privacy and protection, QoS breach prevention and mitigation. The set of storage services has to be accessible by multiple clients in the edge-to-cloud space, and must also have a light footprint, to be executable also on lightweight edge devices with limited resources and horsepower. The CHES subsystem will offer innovative enabling features, supporting the heterogeneity of devices, their mobility, overcoming the difference of storage formats and data types.

Resource-aware adaptation

This innovation in CHARITY addresses the problem of finding the best trade-off between the performance request of an XR application, demanding potentially unlimited scaling capacity, and the cost constraints posing an actual cap on such scaling room. This part of CHARITY aims at maximizing the usage of edge resources to successfully achieve this trade-off, in particular granting the latency requirements, typically among the most critical for XR applications. The designed adaptation mechanisms is based on the MAPE-K loop – Monitor, Analyze, Plan and Execute [11] approach, introducing a Mesh Service between the application and the management layer of the MAPE K Loop to allow service re-routing according of the available resources in order to guarantee the target QoE of the running application, or to reduce it in case of loss of available resources. This adaptation strategy has a strong interaction with the monitoring subsystem, whose inputs can trigger a process of adaptive reconfiguration, since it has to follow the potentially wide fluctuations of resource availability within the runtime environment. The adaptivity must include support of multi-tenant scenarios, meaning that the adaptation parameters can be different for different users, or classes of users of the running application.

Other enabling XR technologies

Other XR enablers under development include:

- Optimization of realistic VR simulation. This will be achieved through investigation on how to improve the performance of rendering exploiting multi-threading and dissecting the physics engine to improve the physical simulation. This work is conducted in the ambit of the Task 3.1 to support the needs of the UC2-1 VR Medical Training Application.
- Custom Point Cloud encoder/decoder. Existing standard to compress, transmit, and decompress point cloud may be insufficient to reach the needs of certain, high-demanding, XR application. A custom view-dependent PC E/D is under investigation in the Task 3.4 to achieve high performance in terms of encoding/decoding time to address the need of the UC1-3 Holo Assistant.
- Advanced video streaming environment with editing capabilities, supporting the peculiar requirements of XR applications. These technologies are under development in the context of the UC2-2 VR Tour Creator Application.
- Mesh Merger. An innovative data service to allow efficient updating of real and virtual environment. This service, under development in the Task 3.4, is particularly useful for multi-user AR games, and it will be integrated in the UC 3-1 Collaborative Gaming.

1.2.3 Actions for boosting innovation outreach

1.2.3.1 Innovation management guidelines

CHARITY offers a solution encompassing a technical architecture and advancements in different technological areas, ultimately allowing the development of a cloud computing continuum platform supporting new emerging application domains and cloud-based services, e.g. a subset of highly attractive innovative immersive communication applications including Virtual Reality, Augmented Reality, and Holography (known as XR).

CHARITY is developing strategies to properly keep under control the innovation grade of its planned technical results, and be ready to take viable corrective actions in case feedbacks from the external environment suggesting such changes are captured and decoded. The innovation approach includes continuous monitoring of the market and proper interaction with key stakeholder communities, to better prepare for the exploitation of the project's outcomes. Another component of this approach is an internal process of following the project technical developments, to capture and properly manage the key innovation value propositions offered by the realized assets. This is happening through a continuous cooperation and communication among the project partners, to ensure a complete and prompt identification of potential or actual innovations. In fact, in a highly dynamic market such as XR & immersive communications one, just tracking technological and product evolution is an important task by itself due to the amount of investment that is being deployed, and to the market expectations in terms of users, as can be seen in this figure from BCG in April, 2022[4] :

[4] https://www.bcg.com/publications/2022/a-corporate-guide-to-enter-the-metaverse-explained?utm_medium=Email&utm_source=esp&utm_campaign=none&utm_description=ealert&utm_topic=none&utm_geo=Global&utm_content=202205&utm_usertoken=CRM_8427312efe35f4db5b187c0dbf583fb6df8df494

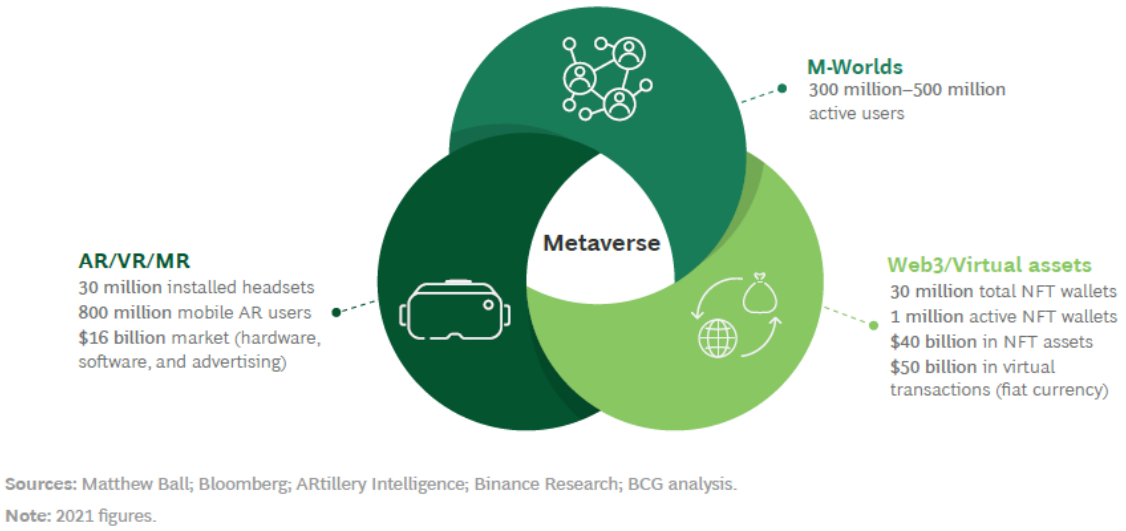

Figure 10: AR/VR market

As it can be seen in the picture (2021 figures), there are already more than 1.000 million active users of XR applications in the world. Therefore, our activities regarding innovation outreach are trying to connect not only with project stakeholders, but also, when possible, with a small portion of these interested final users that already active in the XR world, capitalizing on their possible interest in any of the Use Cases that CHARITY project is developing.

1.2.3.2 Actions for stakeholder engagement

CHARITY addresses a large list of stakeholders in the cloud, telecommunication and infrastructure markets interested to provide advanced media solutions as part of their portfolio. For the application providers and developers, it also offers new market possibilities for expanding their solutions to a broader audience to expand their business services. In all the cases market reality and expectations are truly important for all of these companies as can be seen in Figure 11:

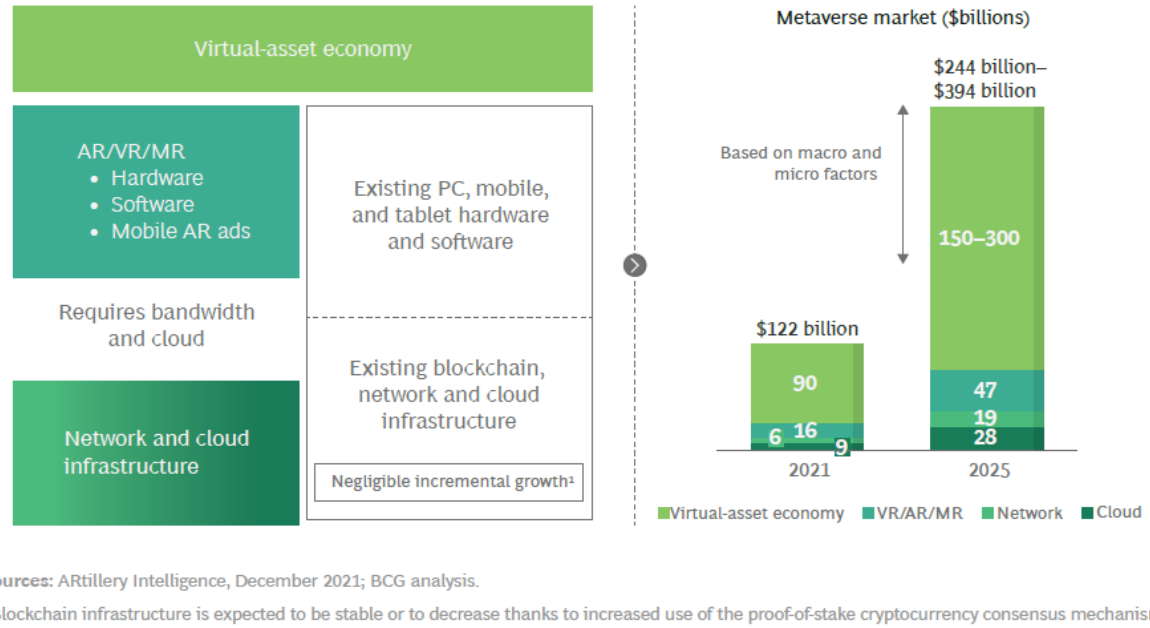

Figure 11: Market figures

Knowing all this, our plans were clear from the very beginning to address these stakeholders. Unfortunately, COVID 19 pandemic has deeply impacted the development of the planned activities since F2F meetings were not allowed and it was also impossible to attend potential conferences and webinars. These barriers were partially resolved with a huge number of videoconference and online collaboration between all the partners as well as with external stakeholders.

At the same time and through online means the project has also established connections with European and non-European XR niche players, mostly SMEs, trying to establish different cooperation/collaboration schemas so as to reinforce outreach of CHARITY innovations in different technological areas.

CHARITY project considers an efficient set of activities including participation in a wide range of events such as scientific conferences, workshops, seminars, innovation events which will add value to the project and its objectives. Besides this the project is also extremely active in setting up collaborations with sibling European projects that are also dealing either with edge/cloud matters or with projects actively working in XR and immersive matters. A non-complete list follows hereafter:

Table 2: CHARITY sibling projects

Name of the project	Program	Main area	Type of collaboration
H-CLOUD	H2020 Sup. Action	Cloud	Cross communications, webinars, newsletters, etc.
HUB4CLOUD	H2020 Sup. Action	Cloud	Continuation of HCLOUD in September
SWForumEU	H2020 Sup. Action	Development	Cross communications
ACCORDION	H2020	edge/Cloud/NextGEN Applications	Cross communications, webinars, newsletters, joint papers, etc.
ARETE	H2020	AR tools for education	Cross communications, webinars, newsletters, etc.
ARTWIN	H2020	AR Cloud based tools for industry	Cross communications, webinars, newsletters, etc.
Iv4XR	H2020	Verification for XR based systems	Starting collaboration
PHYSICS	H2020	Cloud	Starting collaboration
THETA	ERASMUS	XR tools for tourism teaching	Exploring XR applications

At the same time, the CHARITY project is tackling communities of users not only in the industry or research fields, but also on the final users and citizens groups, that will enter in contact with CHARITY innovations and results. This work is being done by some of the Use Case partners in the project. The idea is to pursue the dissemination of innovation results in deeply interested user groups like the following:

Table 3: Target user groups

Use Case	Target User group
VR Medical training	Doctors and nurses
Manned-unmanned operations trainer	Pilots
VR tour creator	Tourism businesses
Holographic concerts	Musicians and art businesses
Collaborative gaming	Gamers

All these activities will grow following the technical advanced of the project that, as was previously mentioned, is still in its first phase.

For a detailed report on all the dissemination activities in which innovation outreach is treated, please take the public D5.2 deliverable of the project as reference.

1.2.3.3 Interaction with the Advisory Board

The CHARITY consortium comprises research institutions, business development departments, infrastructure providers, service providers in several vertical markets, end-users and it is also extended with policy makers, standardization bodies, and external research communities. Apart from that, and to complement this breed of expertise, the external Advisory Board (AB) includes experts from business and research areas and act as external consultancy point for assuring the quality and relevance of the research conducted by the project. The planned activities of the project include constantly collaboration with the AB, so the major technological and scientific results of the project to be met.

As the project is still in its first phase of development the main activities performed with the AB has been just informing them about CHARITY project's advancements. A series of activities is being planned for the second phase of the project, in which the whole AB or part of their members could be invited speakers in project webinars and workshops. It is also planned to have a kind of rehearsal internal meetings with the AB in order to show innovation results in terms of algorithms and their performances, technical architecture and its implementation, etc. In such meetings their advice will help in the final development of the technical works.

2 INTERIM EXPLOITATION PLANS

The current section presents the exploitation plans for all the project partners at the current project point in time (month 18). The exploitation plans, especially for industrial partners, have a strong dependence upon the availability of consolidated assets and learning, with a clear, consolidated definition of their technical structure and of their achieved readiness level. At the current project stage, where an architecture has been defined but the component implementation is still in its early progress, the exploitation plans are still at a budding level, where they have more the shape of strategic guidelines. Exploitation plans will be refined and turned into more precise actions towards the end of the project, as normal in collaborative research initiatives like CHARITY, once the project has gone through the phases of technical prototyping, and extensive evaluation campaigns have been performed.

Notwithstanding this interim phase of the work, all the CHARITY partners started to look at the general market scenario, as summarily outlined in section 1.1, what their main exploitation interests and related macro-level strategies might have evolved with respect to what had been indicated in the DoA a couple of years ago. For most partners the scenario has not undergone substantial changes insofar, nevertheless everybody made its verification exercise, including the academic partners, whose exploitation drivers are far different from the ones of industrial partners. The following pages report the results of this effort.

2.1 Industrial partners

2.1.1 ICT-FI

During the last two year since the CHARITY proposal, ICT-FI exploitation plans are still in line with what was proposed back then. The results obtained up to now in CHARITY are helping ICT-FI to build their internal systems. Currently, CHARITY has proposed a cloud-native architecture to support XR services. The lessons learned while designing CHARITY platform is helping in the design of city-digital twinning platform, a product that ICT-FI is implementing. Indeed, leveraging advances from future wireless networks, machine learning, and network and service orchestration is tremendously helping to implement these internal products. Also, one of the envisioned products is to consume the data generated and gathered by the digital twinning platform using VR technologies. From one side, CHARITY will be helping in integrating VR into ICT-FI current solutions and on the other side, once CHARITY platform is deployed it can be used to easily deploy VR applications, and thus extend the capabilities of our solution.

In the remaining time period of the project, we expect to gain more insight in building cloud-native applications. Such as CHARITY's target use cases, building a real-time city-digital twinning solution requires tight processing and networking deadlines. Moreover, the load exerted on the underlying platform can be even greater than most XR solutions. Therefore, the modules being implemented for service orchestration can be re-used or even enhanced and adapted to our other internal solutions. Finally, ICT-FI is also attracting more funding with these new solutions and also by extending the achievements of the CHARITY project.

2.1.2 ONE

During the first 18 months of the CHARITY project, ONE has been investigating and refining various cloud-native solutions for supporting the next-generation of XR services. Namely, ONE is researching and developing specifically tailored approaches for scheduling XR applications, considering the network and computing environments. Additionally, ONE is exploring the security and privacy aspects of cloud native environments and how that impacts the security of XR applications. Whereas at this stage some of these achievements are still preliminary and under heavy development, they enhance ONE's service offering portfolio in the cloud and continuum orchestration domains. The participation

in CHARITY, in line with the company's business approach, will also allow ONE to advance its knowledge in related topics and pass that knowledge to its core business. Moreover, ONE will leverage the knowledge from the advanced media use cases to leverage new business opportunities in the AR, VR and Holographic domains.

2.1.3 HPE

In the timeframe occurred since the submission of the CHARITY proposal (June 2020), the service business strategy of HPE has gone on consolidating on its pillars, in continuity with the rationales driving it two years ago. The business portfolio and offering of the Business Unit actively involved in CHARITY (HPE PointNext A&PS) is more and more focused on technologies and solutions supporting our customers in their digital transformation process, one of whose leading elements is moving challenging workloads into a cloud-native fashion. After the first phase of the project, we can affirm that CHARITY objectives are fully in line with such business driver, and are in the position to enhance its realization.

A particularly relevant place in HPE potential exploitation is taken by the main component that HPE is currently designing and implementing, i.e. the slice blueprint editor that is part of the XR Service Exposure and XR Service Blueprint Template Repository architectural blocks. This component supports a guided and facilitated specification of the slice blueprints utilized by CHARITY to deploy and manage its XR applications. It is expected to generate outputs in TOSCA language, that is a widely recognized de-facto standard in the service orchestration realm. A tool like this might be for instance a greatly valuable enhancement to the extensive HPE Pointnext offering for telecommunications operators and CSPs (Communications Service Providers), encompassing the whole span of IT infrastructure solutions to enable 5G service deployment, NFV implementation and so on. The slice blueprint editor may be leveraged as a suitable baseline or add-on to realize for instance VNF on-boarding solutions, as well as to interface service orchestration modules like the CHARITY one.

Going beyond the slice blueprint editor, and sticking to the technology bricks defined up to now, there are other acquisitions that HPE might exploit from CHARITY. One example is the expertise matured on Keycloak, an identity and access management component that may be extensively applied and reused in containerized environments, and as such can become another addition to the proposal of bespoke solutions for customer transitioning to cloud-native environments.

Potentially, the most valuable acquisition for HPE might be the experience of deploying a specific class of high-end applications (XR applications and services) into a cloud-native scenario. HPE is proposing an innovative, market leading cloud- style deployment solution like GreenLake [5], as well as solutions for on-premise infrastructure environment like HPE Ezmeral[6] or the HPE Container Platform. CHARITY offers an outstanding opportunity to investigate and learn how advanced XR applications should optimally be deployed in a cloud manner, enabling the creation and tweaking of tailored solutions on top of the existing platforms. In perspective, these learnings can also be applied to other classes of applications exposing critical elements like the XR ones (e.g., strict latency requirements), capitalizing on the very large cross-industry customer basis of HPE PointNext A&PS.

[5] https://www.hpe.com/us/en/greenlake.html

[6] https://www.hpe.com/us/en/software.html

2.1.4 TID

Telefónica I+D (TID), the R&D group of Telefónica focuses always on exploring cutting-edge ideas, concepts and practices. Moreover, these exploration of new ideas, concepts and practices creates the cornerstone for developing advanced products and services, and the improvement of products and services that are already in the market.

A particularly relevant place in TID potential exploitation is taken by the current cutting-edge research on computational resource allocation algorithm and on the obfuscation of network topology. TID has plans to introduce the results of both main projects and edge storage to Telefónica Operating Businesses, by running demonstrators and trials, seeking to find applications within their businesses. As part of a global telecommunication provider, it will ease the collection of knowledge from additional experts, as well as the assessment and evaluation of results in (next-to) real environments.

2.1.5 CAI

Previous studies and investigations carried out within the Training & Simulation business of Collins Aerospace into the feasibility of deploying flight simulator components on the cloud or edge identified key challenges and obstacles. Chief amongst these was network link latency and intermittent jitter on the link resulting in stalls in the media stream. The use of XR headsets in combination with cloud deployment seemed a leap too far as latency demands and jitter intolerance would be exacerbated.
In combination with key CHARITY infrastructure and architecture redesign carried out for the Collins Use Case, we hope to demonstrate a path forward for XR cloud-based flight simulation and champion its adoption within the business unit.
A cloud-based deployment avenue, coupled with XR, could open up new markets and opportunities across the training and simulation business enabling lighter, cheaper and more mobile simulators. The research and work being carried out within the CHARITY project is already attracting significant interest within the business unit and we hope to grow this interest as we progress further with our investigations and demonstrations.

2.1.6 ORAMA

ORAMA is innovating in the field of experiential simulation for medical training. Its strategic mission is to make high quality medical training more accessible and affordable to achieve a tangible impact on quality of healthcare worldwide. Under this prism, the business strategic planning, aligned to the CHARITY vision, aims to support the seamless VR medical training of multiple users in a device-agnostic way, embracing the SaaS paradigm and untethered operation without sacrificing latency. ORAMA, as a deep-tech start-up, observes and evaluates new technologies that may upscale its solution. In this case, the domain of cloud-based services and 5G/6G technologies are mainly investigated regarding the value they bring in for XR technologies. To this end, ORAMA leadership, product and business development teams, will evaluate the developed prototype at the use case showcasing phase.

ORAMA's current commercial solution provides a suite of products, installed and run on untethered HMDs as a single application. The exploitation of the CHARITY functionalities and infrastructure and 5G technologies will minimize the end-user's hardware requirements and will eventually transform the current business operation, as the use of even low-spec HMDs will also be allowed. As a result, the potential market of the company is expected to increase. The technical project team, the MAGES platform engineers (cloud team) along with the product development team will review the technical details on the developed prototype for releasing a beta version of the application module. The business team will be engaged in further dissemination activities to existing customer base.

Several interactions between the technical and the product development teams, prior to the product's release, will be impacted due to the potential adoption of project results and requirements (installation and network communication) in the suite of products. As such, the technical along with the product development team will review the technical details on the developed prototype for

packaging and potentially releasing a beta version of the application module, while the business team will be engaged in further dissemination activities to the existing customer base.

Privacy policies also need to be revisited to support the new type of application based on the SaaS paradigm, while adhering to GDPR. For this reason, the legal department in collaboration with platform engineers and project technical team will validate the GDPR requirements.

The company already has a dedicated team supporting cloud-based services for the platform and has the technical competencies to support the transition. A further expansion of the company's cloud team with additional developers in networking topics will be considered. The team of platform engineers and product development will be trained on the new application modules.

The transformation of our application to a SaaS model will bring a significant change and require an adaptation in all teams in the company. To accelerate this process, a company-wide demonstration of the novel aspects, the benefits, and the implications of the redesigned application as well as a further training of the business team will be of great necessity.

2.1.7 ORBK

UC3.1 provided by ORBK is an AR multiplayer mobile sandbox game that will use CHARITY resources, network orchestration capabilities and XR Services. XR Resource Discovery, Indexing and Planning will be used for optimal resource allocation to enable the Game Server automatic deployment process. XR Resource Monitoring, XR Services Blueprint Templates and Enablers will be used for deployment maintenance and automatic game server deactivation. Main challenge for this UC is precise and constant synchronisation of the mixed environment that players are in. This includes parameters like position and rotation of each user but also multiple virtual objects that are in the simulation. Large amounts of data that needs to be very frequently updated and synchronised between the game server and all participants also pose challenges with the network infrastructure.
AR games currently available on the market provide limited experience in terms of interaction between players, real environment and virtual objects present in the game simulation.
Working on the UC allows us to understand and overcome key difficulties that we are facing during the development and research process. Our ambition is to prove that it is possible to build a very solid base for complex Augmented Reality simulations. As a result, we will acquire a solid base to create convincing AR games with interesting gameplay.

2.1.8 PLEXUS

PLEXUS view on the strategic importance of CHARITY project remains the same since the submission of the CHARITY proposal (June 2020). CHARITY is foreseen as a tool to enrich advanced technological capabilities within PLEXUS core business and, in fact, as a mean to develop more powerful products for the different markets and economic sectors in which the company works.
PLEXUS' portfolio is composed of a mix of technological services and products and in both areas positive impacts are expected from CHARITY project.

In fact, the product portfolio and related offering is where a more rapid benefit is expected from the technological developments and advanced solutions being developed in CHARITY project even in this first phase of the project. The products involved and the improvements expected are:

- Quenda. Quenda is an appointment and waiting management solution suitable for all sectors such as Public Administrations, Telecommunications, Banking, and Retail. It is a modular and customisable system depending on the needs of each client or entity, which manages over 150 million appointments per year. PLEXUS is exploring the possibility of incorporating a digital holographic assistant as an advanced feature in order to help final users in the interaction with Quenda product.
- Quenda Medic. Quenda Medic integrates with existing patient management and EHR platforms on the market and provides workflow tools for managing waiting in waiting rooms

in healthcare settings. It incorporates features for patient identification, routing, calling, obtaining proof of attendance, satisfaction assessment, and statistical analysis. The product is installed in more than 130 hospitals in Spain, Portugal and UK. As a hospital is a complex environment for many citizens and patients PLEXUS thinks that by adding a holographic assistant the UX will be improved.

- GESAC is an advanced system for comprehensive management of HR activity. Customised for each of our clients. Again, a digital holographic assistant would ease the UX for its final users.
- Anblick. ANBLICK is the digital signage system developed by Plexus. It is an advanced multi-platform solution that allows each client to manage any type of screen and the playback of various content in a visual and impactful way. Nowadays PLEXUS has more than 10.000 screens connected to Anblick central system in different countries. A holographic assistant is being analysed as a possible improvement for this product.
- Consultame is PLEXUS' video-care system which can be tailored to the customer's needs and has many potential uses for hundreds of users in a corporate, affordable, and secure way. CHARITY might help PLEXUS in showing if, for health customers, VR and holographic displays could ease the interaction among users.
- Plexus AR game. PLEXUS is involved in CHARITY UC.3 as a way to capture capabilities in advanced AR gaming so as to define a product evolution for the ACCORDION PLEXUS AR game.

Regarding the PLEXUS' service offering, it is important to mention the potential exploitation of the work being undertaken by PLEXUS (and other partners) in areas like **monitoring** of the different components of CHARITY platform that must support the requirements of XR applications to be developed on a multicloud platform, reducing complexity and focusing on **prevention and reactivity in** ecosystems with **heterogeneity of technologies**. Besides this work and sticking to the technology bricks defined up to now, PLEXUS is actively working on network resource orchestration issues and this is another acquisition that PLEXUS might exploit from CHARITY. Without any doubt the most valuable acquisition for PLEXUS is being the experience obtained in the relation with the different UCs defined in the project that is allowing PLEXUS to obtain specific experience in designing and deploying different classes of high-end applications (XR applications and services) into a cloud-native scenario.

The knowledge and capabilities being obtained in this first phase of the project and the expected from its second part would be somehow incorporated in the following PLEXUS service offering:

- PLEXUS monitoring services for complex technological customer solutions in terms of infrastructure, communications and applications.
- Advanced network orchestration solutions to be analysed in terms of security and performance within SLICE 5G Cybersecurity project.
- Advanced VR capabilities to be incorporated in web development services for Hotel and Tourism industry customers.

2.1.9 DOTES

DOTES use case (Cyango Cloud Studio) is completely web based, which allows us to plan cloud features to increase the usability of the software. All the development that is being made within CHARITY is allowing us to progress a lot our software services. We are migrating and breaking every component into micro-services that can be easily scaled and used in CHARITY cloud, this makes the whole platform an easy deployable solution using modern standards and technologies. Our roadmap is ambitious. One of the most ambitious features we want to implement using CHARITY is the online video editor. This is clearly a feature that can use all the resources and services CHARITY has to offer. After spending months of development on UI/UX and code re factoring and optimization, we are almost reaching the stage where we will develop this video editor feature. The knowledge and capabilities we are getting from being in CHARITY are very important for our progress and success in the market.

2.1.10 HOLO3D

The exploitation strategy of HOLOGRAMA3D has not undergone substantial changes with respects to what had been indicated in the submitted proposal. Holo3D still plans to capitalize on its wide customer base in the multimedia industry market, increasing the value of its existing differentiating assets (ranging from multimedia production technology to 3D advanced expertise). Ultimately, the envisioned target is to enable the "cloudification" of the applications proposed in the CHARITY use cases, thanks to the capabilities that CHARITY will provide, with the related extension and enhancement of the proposed service portfolio.

Table 4: Exploitation plans 2022: HOLO3D Holographic Meeting

2022 Q1	2022 Q2	2022 Q3	2022 Q4
Identified the GUI configuration for a friendly interaction for the first-time users.	Design of the GUI and local testing of GUI elements	Plan to move (along with partner DOTES) to an online, cloud-based APP based on our GUI requirements. As an alternative, we start programming the cloud-based video editing tool.	Migrate completely to the cloud-based video editing tool app. As a local solution is mandatory for the client PC (that sends the video signal to the Holographic device) we will develop the local (windows based) app.

Table 4: Exploitation plans 2022: HOLO3D Holographic Concert

2022 Q1	2022 Q2	2022 Q3	2022 Q4
Identified the GUI configuration and synchronization tests.	Continued the synchronization tests. So far, the conclusion is that, while the Musicians can all synchronize to a single ticker, it is almost impossible to synchronize between themselves, since there is no conceivable way to hear each other in realtime, if they are all in different geolocations.	Plan to move (along with partner DOTES) to an online, cloud-based APP based on our GUI requirements. As an alternative, we start programming the cloud-based video editing tool	Migrate completely to the cloud-based video editing tool app. As a local solution is mandatory for the client PC (that sends the video signal to the Holographic device) we will develop the local (windows based) app.

2.1.11 SRT

SeeReal Technologies plans in using cloud-based services for future developments of holographic 3D display technology in the automotive area but also for end user devices and so exploits scientific results and technology gained within the CHARITY project. This improvement then would certainly be used by partners and customers which adapt holographic 3D display technology from SeeReal. Especially developments in the area of 3D point cloud data formats, compression, decompression and transmission combined with cloud-based rendering and processing are of big interest. Currently this very novel true holographic 3D display technology still needs comprehensive and fundamental development, products are not available yet and will possibly not be available within the next 2-3 years. Nevertheless, the research done within CHARITY could be adapted and exploited to projection-based types / pseudo holographic technology, easier to manufacture and already available on the market.

SeeReal Technology is a design house performing fundamental research in the field of true holographic 3D, but will not develop products. For demonstration purposes, individual holographic 3D display prototypes exist. Within the context of private demonstrations, it would be possible to show the results of CHARITY to a limited audience but typically under NDA. Therefore, the results gained within CHARITY could at least be exploited to future partners developing products based on the technology developed by SeeReal.

2.1.12 CS

One of CloudSigma's main roles during the project is to provide cloud infrastructure as part of a multi-layer and multi-domain testbed environment to facilitate the development of the CHARITY framework components and to support the Use Cases. As a commercial cloud provider, this is essentially a production cloud environment running CloudSigma's proprietary cloud platform. Project accounts have been set up and resources allocated based on the current project requirements.

During the writing of the original proposal, it was determined that the existing CloudSigma product portfolio can be used to advance the key concepts being explored by the CHARITY project while attempting to address issues related to the provisioning of microservices across multi-cloud environments, while meeting the anticipated network latency requirements. By making optimisations at the infrastructure layer CloudSigma intends to meet the infrastructure requirements in relation to the workload characteristics and requirements of the interactive services demonstrated by the VR/AR and holography Use Cases. As a commercial cloud provider, it is extremely beneficial to gain deeper knowledge of the potential computing, storage and networking requirements of real-world use-cases, especially of such emerging technologies where this data is still relatively unknown.

As the project has progressed, CloudSigma has started to gain a deeper insight not only into the resource management requirements, but also the expected performance, particularly in relation to network latency and a number of key network security requirements. This is expected to continue and evolve over the remaining course of the project. CloudSigma's involvement in the CHARITY project helps the company to be better positioned to consult customers in this field and to be able to select and offer suitable infrastructure to vendors of these technologies and services. CloudSigma's operations team expects to use the project results to improve QoS and QoE, and ultimately improve the company's positioning in the market. More specifically, CloudSigma intends to take advantage of efficient AI techniques and zero-touch network slice life-cycle management (ZSM) mechanisms used for the orchestration and life-cycle management of the microservices. More specific commercial opportunities are expected to arise closer to the successful completion of the project. The technical and commercial viability of all outputs from the project will be considered, as well as opportunity for further collaboration with project partners.

In summary, facilitating cloud services for partners from different industry sectors gives us valuable insight and experience in offering relevant and suitably configured infrastructure, based on different workload profiles.

2.1.13 EURES

As a major European R&D management firm for the telecoms sector, EURES will use selected CHARITY project results to strengthen its consulting competency. This will enable EURES to keep providing leading-edge consulting and support services to leading European telecom operators, who are shareholders and clients of EURES. More specifically, EURES will use the insights gained from the CHARITY project to consult and support European telcos in their innovation strategies for cloud technologies and services, with a specific focus on cloud challenges related to future advanced media solutions based on XR technologies, or overall applications and use cases that have extreme requirements for their implementation.

EURES is not planning to create any foreground intellectual property based on the technical results created in CHARITY. This is due to the role of EURES in the project, which is focused on management and dissemination. Thus, the exploitation strategy of EURES will be focused on the knowledge gained in the process of generating the technical results of CHARITY.

This exploitable knowledge will particularly include: (i) deeper understanding of XR technologies, providers, and markets; (ii) insights on technological challenges XR technologies pose for 5G and beyond networks as well as cloud/edge networks in delivering immersive user experiences; (iii) new insights on market opportunities related to specific vertical sector applications of XR-based use cases and their technological and investment requirements for telcos. The participation of a big number of use case partners in CHARITY from various application domains makes this of particular interest to EURES.

Based on these types of exploitable knowledge, EURES is planning to consult and support its telco clients in exploiting the emerging opportunities at the cross-section of novel XR-applications and their delivery via advanced networks and cloud/edge ecosystems. This will concretely start, once the exploitable knowledge based on CHARITY' technical results has been validated through use cases and supporting market research, which is expected to happen in the last third of the project.

In the post-project phase, EURES is planning to advise and consult its telco clients in the definition of further joint collaborative undertakings that build on emerging issues identified in the CHARITY project in the context of new XR-based services over future services and networks. In this way, the exploitation plan of EURES aims to utilise the knowledge gained in CHARITY to be used for helping European telcos to develop and implement efficient cloud architectures and cost-effective solutions as prerequisites for new immersive communication and interaction services with extreme requirements.

2.2 Research/University partners

2.2.1 CNR

CNR is the largest public research organisation in Italy and a top-level R&D performer in Europe, being the fourth beneficiary of the EU FP7. CNR participates in the CHARITY project with its largest institute focused in ICT, the "Istituto di Scienza e Tecnologie dell'Informazione" (ISTI, http://www.isti.cnr.it), located in Pisa. CNR-ISTI is committed to producing scientific excellence and to playing an active role in technology transfer. The domain of competence covers Information Science, related technologies and a wide range of applications.

CNR-ISTI participates in the CHARITY project with two laboratories: the High-Performance Computing Laboratory (HPC Lab) and the Visual Computing Laboratory (VC Lab). The HPC Lab (http://hpc.isti.cnr.it) at ISTI conducts research in various areas of High-Performance Computing, including Large and decentralized infrastructures, Edge computing, Energy-efficiency Large-scale Data Analysis, Efficient Machine Learning, Information Extraction and Semantic Enrichment. These skills are fundamental for the R&D activities proposed in CHARITY. Specifically, the competencies on Distributed platforms, including Grid, Cloud and Edge, were applied in EU-funded projects dating back at least to FP6. The HPC lab has continued to cultivate and evolve a related collection of background results and

technologies that has supported and extends to most recent H2020 project results. The VC Lab is a laboratory with more than 20 years of experience in R&D in Computer Graphics. The main research topics of the laboratories are 3D digitization, computational fabrication, interactive graphics, and the development of innovative Computer Graphics applications for Cultural Heritage. In this field the VC Lab has been developed techniques and algorithms for the efficient management (processing, streaming, compression) of huge amount of geometric data. The laboratory has been involved also in XR European projects such as the H2020 EMOTIVE project (Virtual cultural Experiences through personalized storytelling). This expertise is very important in the ambit of the CHARITY project.

As a public research organization and according to its statutory aims, CNR supports and contributes to both knowledge and technological transfer. By means of CHARITY outcomes, CNR will thus both advance its research activities and foster new industrial partnerships and technological transfer opportunities.

Concerning CHARITY research, **knowledge transfer** and **dissemination** will mainly focus on

1. enhanced and advanced solutions for orchestration, resource management in distributed and heterogeneous scenarios, as well as
2. innovative algorithms for advanced XR applications, such as the point cloud compression and the multi-user synchronization of virtual environment for sophisticated Augmented Reality applications.

The CNR CHARITY team will transfer and share the acquired technical and scientific knowledge with other researchers in CNR as well as with international research teams and communities aiming at the same scientific goals, with universities and research institutes. Striving at creating, advancing and disseminating this body of knowledge will also fertilise new collaborative research work to face innovative and challenging problems. The project is already bringing **new long-term collaborations** and supporting **renewed ones** with other institutions, e.g. **research** CHARITY partners like HUA, and **industrial** ones like HPE, SRT, ORBK and PLEXUS.

As a further positive fallout, the knowledge transfer also involves **education** activities, as the CNR team in CHARITY

1. addresses post-graduate formation by hosting Master Degree and PH.D. students from higher education institution like, e.g., the University of Pisa and the IMT School for Advanced Studies Lucca, allowing the students to interact and collaborate with CNR research activities
2. directly provides higher education formation, thanks to the involvement of key personnel in teaching master courses of the University of Pisa, which can incorporate CHARITY findings and developments.

Concerning **technological transfer** and **industrial exploitation**, CNR will target industrial realities and foster the creation and evolution of its scientific and technical background, to be spent in the active collaborations and liaisons with current and future industrial partners.

Basically, all the components developed within CHARITY to support the previously mentioned topics are candidates for further industrial exploitation. To this aim, CNR channels its contribution to project software artefacts under open-source licenses, either the more constrained ones (e.g. GPL), which maximize diffusion and reuse, or the less restricting ones (e.g. Apache, MIT) that are more readily exploited for technological transfer in industrial collaborations. Open-source licences are also a key factor in the strategy for strengthening the relationship to broader **open-source development communities**.

Double licensing and consultancy contracts in specific business cases are also viable options to allow **industrial exploitation** of results alongside their open community sharing.

Concluding, we can summarize the exploitation strategies in four main directions:

- spending the scientific and technical knowledge acquired in setting up new collaborations both with academic and industrial partners

- publication of results related to the R&D activities, targeting international conferences and journals
- higher education activities, including new personnel formation and attraction
- supporting the technology transfer through the release of code (where applicable/possible), the dissemination of the knowledge acquired during the project and by seeking related industrial collaborations.

2.2.2 HUA

Established in 1991, the Harokopio University in Athens (HUA) is a non-profit, public, higher education institution located in the urban setting of the large city of Athens. HUA is a small (enrolment range: ~2,000 students) focused, coeducational higher education institution. HUA offers courses and programs leading to officially recognized higher education degrees such as undergraduate certificates/diplomas, bachelor degrees in several areas of study. HUA has a selective admission policy based on entrance examinations. According to a study conducted by the National Documentation Centre, HUA is one of the four Greek Universities that have been continuously publishing work that is highly acknowledged and dispose impact levels that lie beyond the world's average.

The department of Informatics and Telematics (DIT) is the fourth and most recently (2006) established department of the University. The mission of the department is to promote Computer science, primarily in the areas of network-centric systems and e-services, so as to provide students with the theoretical and practical skills and competences, which are necessary for the design, development and delivery of technical solutions, in all fields of Information and Communications Technology (ICT). The department also conducts basic and applied research in all areas relevant to ICT funded either by international institutions or the Greek state. DIT has participated in various funded R&D collaborative projects from institutions such as the EC, Qatar National Research Fund, EEA grants as well as projects funded by the private sector. The members of DIT participating in this project are all involved in research related to software engineering, especially in the development of scalable web and mobile apps as well as large scale data analysis and management.

The participating HUA team belongs to the iThink Lab (http://ithink.hua.gr/) which is a mission-driven research unit aiming to improve the effectiveness and impact of research and consultancy initiatives to society and businesses.

HUA brings expertise on adaptive behaviors in hybrid edge/cloud infrastructures at the network and computing planes. In particular HUA leads the effort in Task 2.2 in adaptive network configurations to support the novel CHARITY applications and in Task 3.2 for a novel edge storage. HUA is also involved in standard consortium-wide activities such as requirements, analysis and design, integration and evaluation and dissemination, exploitation and communication.

From a more detailed perspective, HUA is developing the following components:

- Charity Edge Storage (CHES), a distributed hybrid storage component spread across heterogeneous edge and cloud nodes with intelligent decisions on data placement, data caching and considerations on performance (QoE) and security.
- Charity Edge Storage registry which aims at providing a localized Docker registry using CHES as its file storage backend.
- Traffic Prediction Mechanism, a component which is able to accurately predict the expected network traffic within a specified time-frame.
- Resource Usage Prediction Mechanism, a component which can provide accurate predictions regarding future resource utilization.
- Traffic Routing Mechanism, a component which is able to perform dynamic multipath routing based on the network topology, the current network status and the expected network traffic.

- WAN - Wide Area Network - Infrastructure Manager (WIM), a component which is responsible for connecting/stitching the different Virtualized Network Functions (VNFs) within a single domain or across several technological and/or administrative domains.

These components, together with the general involvement of the organization to the project in various tasks and work packages comprise the tip of the edge for the exploitation of the project outcomes. HUA has invested in these components and the associated technologies in order to make an impact in the academic community but also in order to strengthen the university's role in the society and academia.
In what follows, we explain the generic exploitation principles governing the role of HUA in CHARITY and present the activities undertaken in order to implement them, always on the basis of the aforementioned involvement to the project.

Business Opportunities

HUA's exploitation and dissemination activities in the frame of CHARITY are directed towards various directions:

- **Education.** The existing and well-established knowledge and methods combined with the outcomes of CHARITY, will be proliferated among the attendants of the University activities. Due to the advanced nature of this research, this activity will be targeted towards postgraduate as well as continuing education programmes.
- **Technology transfer towards open-source communities and IT companies.** HUA will try to make contributions that derive from the available CHARITY technologies to the open-source communities and to provide direct technology transfer service to the Greek IT industry companies. Furthermore, HUA will try to promote additional joint R&D projects with various organizations extending CHARITY technologies.
- **Strengthening of partnerships.** At local and international level in the pursuit of excellence in the academic and scientific fields.
- **Scientific Achievement.** HUA will promote research and extension of the Institute's scientific expertise, which will enable the organization to keep the leading position in linking the Greek industry with worldwide evolutions in science and technology. The scientific results of the project are presented in international conferences and printed in journals, propagating knowledge through the scientific community and stressing the prestige of HUA and the European Community.

Addressable Market

HUA focuses on research and education, and as such, its addressable market is mainly the research community. HUA already disseminated the preliminary results of CHARITY to the international academic community. More specifically, in the frame of CHARITY, HUA focuses on increasing visibility among the scientific communities that deal with hybrid edge/cloud infrastructures at the network and computing planes, adaptive network configurations and novel edge storage mechanisms and frameworks. To that end, HUA has produced numerous scientific publications on these topics. The majority of them have already been published by venues such as the IEEE International Conference on Cloud Networking and the Journal of Networking and Network Applications while the rest of them will soon be submitted in venues such as the IEEE Transactions on Cloud Computing. Furthermore, these scientific endeavours of HUA will provide opportunities for establishing new collaborations in order to accelerate innovation and to tackle various demanding problems. Even more, the problems posed by CHARITY will foster the creation of a scientific and technical background to spend in the active collaborations and liaisons that are currently active with industrial partners such as AWS Greece. The latter is currently deploying a new service for low latency applications, dubbed AWS local zones, and we have initiated a communication with the purpose to understand how each technology could complement the other.

Exploitation Outcomes

Following this approach, HUA has achieved the following exploitation outcomes:

Education

- 1 PhD student works in the frame of CHARITY
- 1 PhD student started and continue on the basis of the work in CHARITY
- 3 BSc student run side-projects relevant to CHARITY
- CHARITY concepts are gradually introduced in the department's lectures, particularly in the Web Development course.

Technology Transfer

- The source code of the components that HUA developed during the course of the project will be made publicly available in GitHub under an open-source license.

Partnerships

- A collaboration with the Consiglio Nazionale delle Ricerche (CNR) has been initiated in the frame of CHARITY.
- Multiple investigatory communications have been initiated for research collaboration in the topics in which HUA contributes to CHARITY.
- At least one research proposal has been submitted in which HUA was involved contributing expertise acquired in CHARITY.

Enhanced Scientific expertise

HUA achieved the following publications:

- 2 scientific publications have been already published and/or presented to the public in international conferences
- 2 scientific publications have been already published in international journals
- 2 scientific publications have been accepted for publication in international conferences
- 3 scientific publications have been already submitted in international journals

3 Conclusions

During the first period of the CHARITY project, the activities of task 5.3, under whose scope the current report falls, have been mainly focused on three aspects:

- Observe the evolution of the main target markets potentially addressable by the results of CHARITY
- Identify the Innovation value proposition (or propositions) of the CHARITY project, and outline the potential exploitable assets at the end of the project
- Identify/verify the interim exploitation plans of CHARITY partners

This deliverable aims at being the starting point after the first 18 months for the next planned exploitation activities which will further update the market analysis, focusing on the market context for the specific CHARITY components and further investigation on market segments that should in the meanwhile be highlighted as possible targets. Albeit the most detailed information and view about the final results of the technical developments is still ahead to come, the current deliverable tries to offer an overview of the current status, through cross-checks between technical activities and business scenarios, and to summarize how the project is seeking to create a proper impact into the most relevant stakeholder communities.

To convey this interim snapshot, the report is structured in two macro sections. The first one offers a high-level overview of the potentially addressable markets, choosing to focus in particular on the specific XR service markets addressed by the CHARITY partners, to keep a more focused (deep and narrow) view on more specific segments where the impact of the project can more easily be verified and demonstrated. In this section, the report also outlines what are, at the current development stage, envisioned as the most probable and promising assets that the partners of the project might in the future exploit. Finally, the general strategy for managing the innovation produced by the project and reach it out to the key stakeholders has been summarized. The second section presents the individual exploitation plans of CHARITY partners, at this interim phase, matched with the initial exploitation strategic ideas that had sparked the creation of CHARITY a couple of years ago.

The outcomes of the above activities will be completed and reported with the second final revision of the current report (D5.5, to be delivered at project end). At that time, even an analysis of possible business models will be outlined, once the progress of technical results as well as of stakeholder interactions will provide a reasonably solid foundation to make realistic assumptions on possible envisioned scenarios.

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