The role of 5G in the adoption of enterprise Augmented Reality (AR)

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CONTENTS

1 OVERVIEW

Since the first deployments of 5G networks, AR has had, and will continue to be, an important chapter in the book of 5G-enabled applications. Certainly, the common perception has been to associate AR to entertainment and media applications, but beyond that easy hype, AR has always had strong potential enterprises looking to improve their performance and efficiencies. 5G is enhancing that, providing the necessary infrastructure for exploring AR-based enterprise applications not possible before. This article is based on a research on the convergence between 5G and AR conducted by AREA (Augmented Reality for Enterprise Alliance) in 2021.The article examines how the enterprise AR ecosystem perceives the coming of 5G, which enterprise AR solutions can be developed using 5G deployments, what are the difficulties in achieving, and what are the benefits. The analysis is based on a collection of enterprise 5G deployments, covering the period 2017-2021. The overall result shows that the development of 5G-based enterprise AR applications were in an early stage of development in 2021, but there are promising use cases that showed the potential of 5G in driving adoption of enterprise AR applications in various sectors, particularly in manufacturing.

Key words: Augmented Reality, 5G, AR-based enterprise applications, Technology Adoption, Technology Perception, Industry 4.0

1.1 INTRODUCTION TO THE STUDY

This paper is based on a member defined research project delivered on behalf of the Augmented Reality for Enterprise Association (AREA) during the period May-August 2021. The study had an educational and a research objective. The educational objective focuses on the development of training materials on 5G for AREA members. The research objective is aimed to explore the role of 5G in the development of enterprise AR applications in various sectors, particularly manufacturing. The research activities should be seen as a continuation of explorative work AREA is delivering to its members in emerging technologies (including research in the role of AR, IoT and AI). The research project was completed in September 2021. This article is based on the research results, and it assumes that the reader has an understanding of 5G.

1.2 THE RESEARCH QUESTION

The move towards 5G era in mobile communications could create the conditions for a new set of use cases and enhance the sophistication of several others that are suffering by limitations of existing telecommunications networks such as high latency, low bandwidth, and data rates. 5G will not only break existing performance barriers, but it will enable new applications and new business models in a variety of business environments.

AR has evolved dramatically during this decade with advancements in computer graphics, computing, sensing, and hardware solutions. Certainly, those advancements have showed the potential of AR-based solutions in enterprise. However, technological limitations – among others - have restricted the AR ecosystem to show the entire potential of AR-based solutions for enterprises. This research wants to explore if 5G represents the opportunity for the AR

community to break those limitations and develop advanced AR solutions for enterprises thus becoming a useful and critical part of the future of work.

The **key research question of the research** is: <u>if</u>, <u>how</u>, <u>under which conditions</u>, and <u>when</u> 5G will drive innovation and adoption of enterprise AR applications?

1.3   RESEARCH METHODOLOGY

The research team, composed of experts in the areas of the IoT and 5G, has taken a combined research approach. They assessed a vast business and academic literature on the role of 5G in Industry 4.0, 5G-enabled AR solutions for enterprises and the future evolutions of 5G and AR. A database of 5G-enabled enterprises AR projects was produced during this phase of the project.

Following the literature review phase, a primary research phase was completed. This was structured in two steps.

1)   based on a survey of AREA members, aimed to understand the perception of the AR community regarding 5G.
2)   interviews with key stakeholders such as enterprises, primarily manufacturers, system integrators specialised in Industry 4.0 solutions, experts in 5G and AR, mobile network operators, and the AR community.

The interview phase was useful for different objectives: identifying projects not captured during the secondary research phase, learning the benefits of 5G-based AR applications, appreciating the challenges in the convergence of 5G and AR, and gathering ideas on how those challenges can be faced.

The research paper is structured in three parts. The first section illustrates the AREA members survey results on how they perceive the rise of 5G. The second section discussed 5G-based AR use cases in enterprises, stressing benefits and challenges. The conclusive part looks at the future of the convergence 5G-AR.

2   HOW DOES THE ENTERPRISE AR COMMUNITY ENGAGE WITH 5G?

There is a vast academic and business literature on the impact 5G on enterprises[1]. The literature on enterprise AR within Industry 4.0 framework is growing and looking at the role of 5G in enabling enterprise AR applications[2]. Based on that literature, the research team run a survey with the AREA members to assess their level of engagement with 5G. The survey was run during May 2021. 36 AREA members completed the task. Some relevant questions are discussed in this section.

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[1] MIT Technology Review Insights. 2020. 5G and the enterprise opportunity. Content sponsored by Ericsson (*5G and the enterprise opportunity | MIT Technology Review*)
[2] Tariq Masood and Johannes Egger. 2019. Augmented Reality in support of Industry 4.0 – Implementation challenges and success factors. *Robotics and Computer Integration Manufacturing*, 58.

Q1. Are you currently researching, testing, or running PoC on 5G-enabled AR solutions for enterprises in the manufacturing/industrial sector?

61% of the respondents were involved in some form in 5G-enabled AR activities.

Q2. What enterprise use cases are you currently testing with 5G?

Exhibit 1 shows the type of use cases tested by AREA members. 9 AREA members are working on remote maintenance projects, 7 on collaboration, 6 on maintenance, and then others. The project area of maintenance appears more relevant than other use cases.
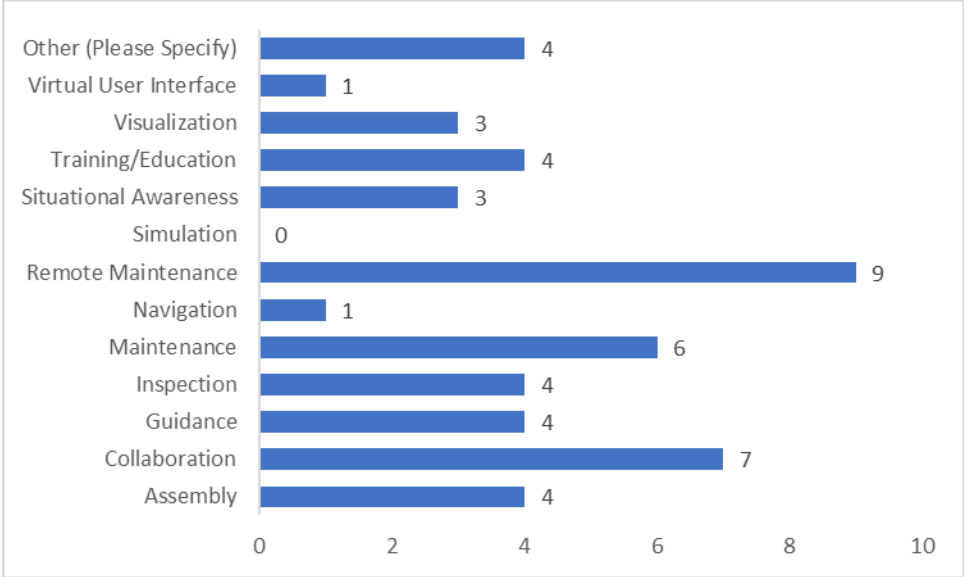

Exhibit 1. Type of use cases currently tested.

Q3. Why are you not involved in 5G-related AR projects?

Exhibit 2 shows the reasons for not being involved in 5G-related projects. The large majority claimed to work with Wi-Fi and locally tethered devices. A combined 15% argued that 5G is not an immediate opportunity because it is in its early stage of development and, therefore, the benefits are not clear.
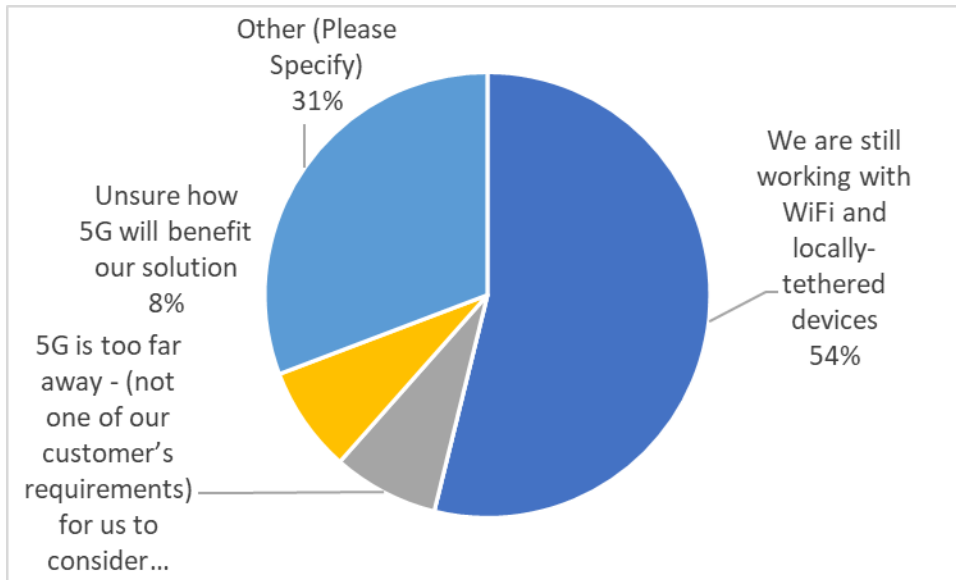
Exhibit 2. Reasons for not being involved in 5G-related AR projects.

Q4. How would you describe your knowledge of 5G?

As shown in Exhibit 3, 53% of the respondents showed a basic knowledge on 5G. They understood the benefits from a telecommunications network point of view. Almost 38% of the respondents had an operational knowledge of 5G-enabled AR applications. That had different levels of sophistication. For example, only 9% of the respondents claimed to have a full understanding of the potential of 5G for AR because they are actively involved in 5G-related AR projects.
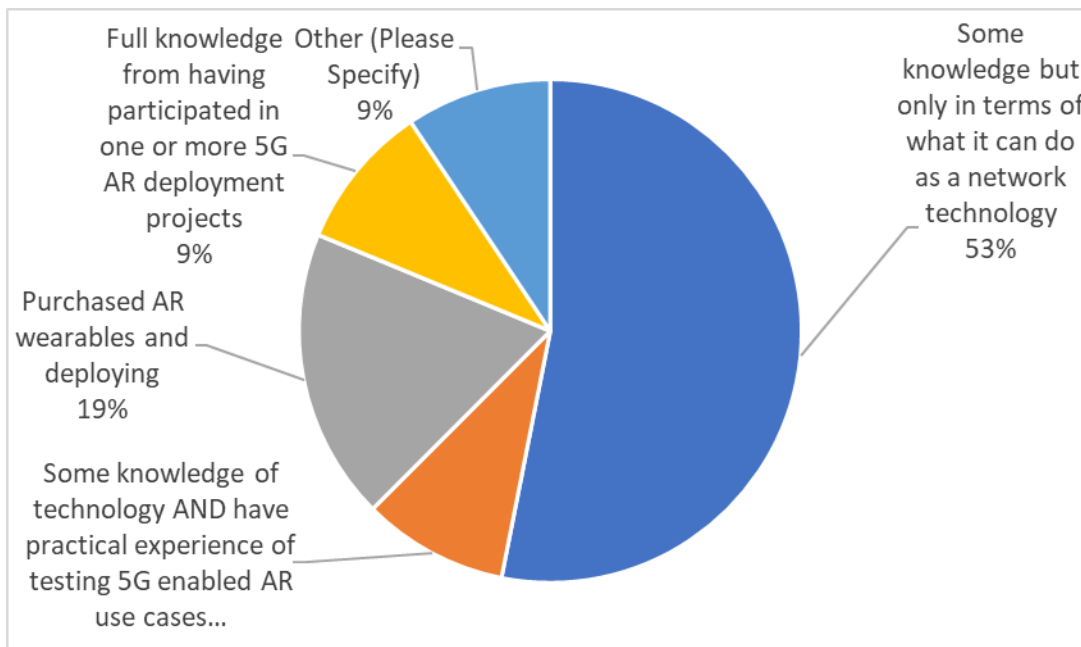

Exhibit 3. Different levels of knowledge of 5G, N=32.

Q5. I believe it is essential to design 5G enabled AR devices specific to industry use cases.

Question 5 looks at the future of 5G and AR asking the respondents if there is the need to design 5G-enabled AR devices specific for enterprise use cases. As shown in Exhibit 4, most of the respondents believed that is necessary. It is interesting to notice that there was one respondent arguing categorically the contrary.
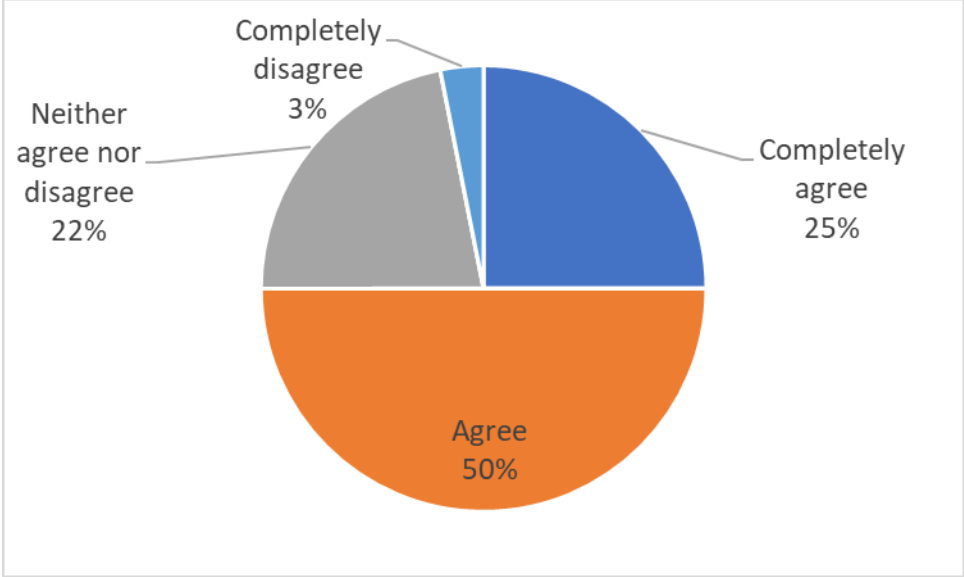

Exhibit 4. Need for designing 5G-enabled AR devices specific to industry use cases, N=32.

Q6. I believe 5G enabled AR will change the way I do my business.

72% of the respondents believe that 5G-enabled AR will change their way of doing business in the future as shown in Exhibit 5. 3 respondents disagreed on that statement.
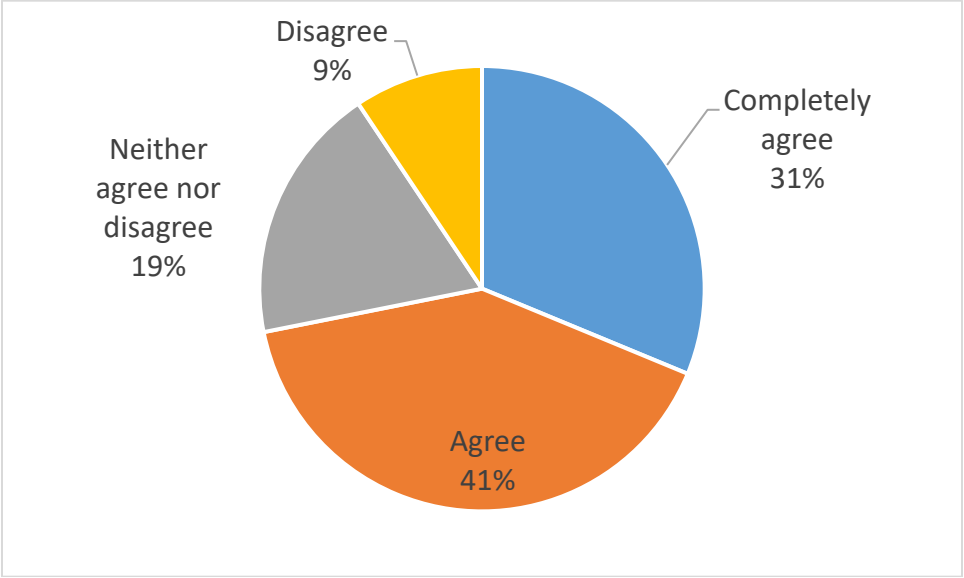

Exhibit 5. 5G-enabled AR will change business modus operandi, N=32.

Q7. When do you think 5G AR devices will be used by most industrial enterprises?

41% of the respondents believed that the AREA community should pay attention on the evolution of 5G because its impact on AR and enterprises will happen in the next 2 years, maximum. Instead, 53% of the respondents believed that there is more time to adjust to the changes 5G will bring, believing that the impact will start becoming relevant in 3 years' time, evolving during a period that goes until 2028-2029.
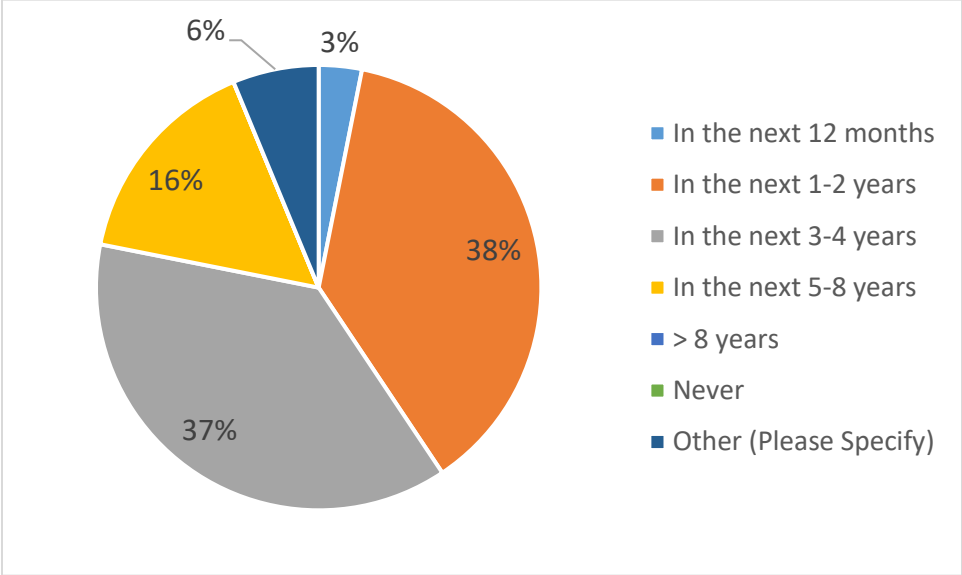

Exhibit 6. Timelines for the impact of 5G in AR for enterprise, N=32.

The results of the survey give a picture of the enterprise AR community divided into two groups. The first group that is observing the evolutions of 5G and its potential implications in AR without planned and strategic actions. The second group, smaller than the previous one, is involved in 5G-based projects in different modes and intensity. The next part of the paper will dive into those projects and the companies involved in, particularly the enterprise AR companies.

3 5G-ENABLED ENTERPRISE AR USE CASES

This chapter highlights the trends of 5G enabled AR for enterprises and illustrates three case studies to draw useful lessons for AREA members. The research team created a database of 5G-based enterprise projects publicly launched during the period 2017-2021. The database was composed of 165 projects[3]. The development or testing of AR-based enterprise solutions was decelerated in 48 projects (29% of the total). Exhibit 7 shows the type of use cases present in those 48 projects.

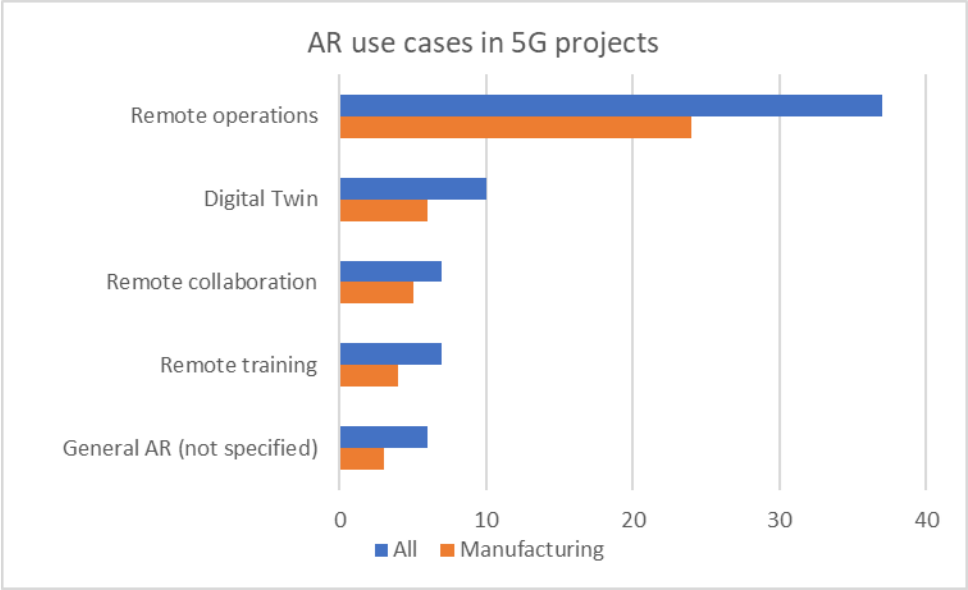[3] AREA 5G and AR research database.

Exhibit 7. Types of 5G enabled AR use cases Source: AREA Research

Of those 48 use cases, some did not specify for what purpose AR is being used. However, many tested multiple use cases. The most cited AR use case was to remotely operate machinery or equipment, testing the 5G capabilities of speed, capacity, and latency. This preference for AR supported remote operations and maintenance is not surprising as it is in line with the results of the survey conducted with AREA members.

What is perhaps surprising is that the explicit mention of combining AR and digital twin overlays was not as common as remote operations. For example, for every enterprise who is testing digital twin with AR, there are 3.7 who are testing for AR enabled remote operations. To smart manufacturing enterprises, the ratio is 1 to every 4. This gap reflects a reality that enterprises, especially those in the smart manufacturing segment, have not yet advanced in their trials to combine both big data sets (eg digital twin) and AR.

Said that, the status of those projects also reflects that enterprises are at the beginning of their journey in 5G-enabled enterprise AR solutions. Exhibit 8 shows the status of the projects.
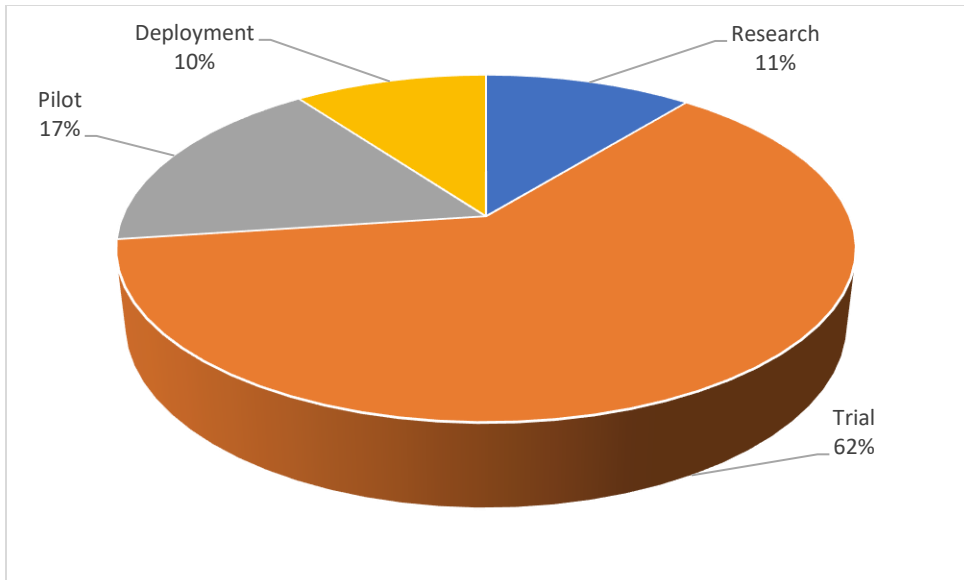
Exhibit 8. Development status of 5G-enabled AR projects Source: AREA Research

More than 70% of the projects were in pre-pilot phase, therefore, in a status of research. That degree of development was also reflected in what types of 5G deployments were used in the case of AR solutions. Exhibit 9 show the deployment methods explored in enterprise AR applications.

Exhibit 9. AR in 5G deployment methods Source: AREA Research –

Note: Terms in the chart are briefly defined in the Essential 5G Glossary at the end of the paper.

The most common configuration and, not surprisingly, were 5G private networks and MEC. As many smart manufacturing enterprises indicated that 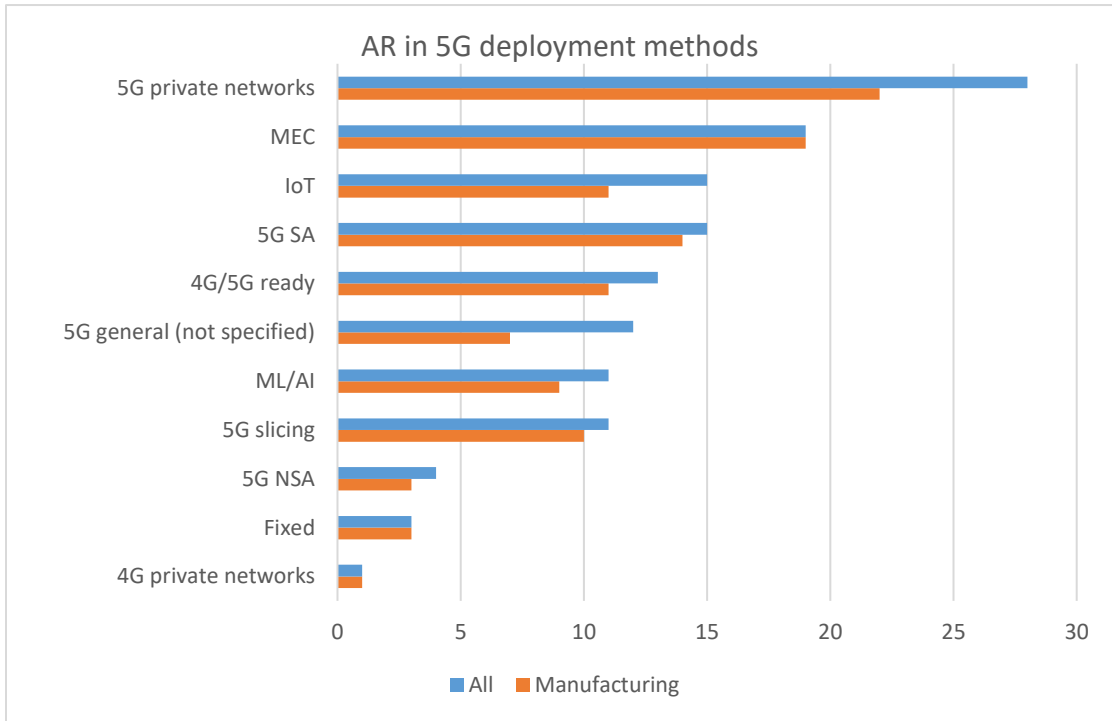they are testing both 5G private networks and MEC unlike the trend seen across all vertical industries. This reflected some degree of curiosity among smart manufacturing enterprises as to how 5G is truly transformational for AR experience together with MEC in an industrial setting.

The following three case studies provide more insights on how companies are approaching the development and use of 5G-based enterprise AR applications.

3.1   5G-ENABLED AR ADOPTION CASE STUDY 1: HAIER'S MULTIYEAR JOURNEY

Haier is a home appliance and consumer electronics company based in China and prides itself to be a world-renowned brand in China and globally . As is fitting to a manufacturing market leader, Haier started their digital transformation journey as early as 2017. They created COSMOPlat, an industrial internet platform to digitalise all factory processes including supply chain and logistics workflows. By February 2021, Haier has deepened their digitalisation efforts by leverage complementary technologies such as AI, IoT, big data analytics, and 3D printing in 2018, AI and 5G in 2019, AI, 5G and MEC in 2020. Haier fully commits to 5G MEC and is now figuring out how to further optimise their business operations.

Technology	5G configuration	5G AR test case
- AI, 5G, Multi-access edge computing (MEC) and industrial internet platform, COSMOPlat	- 5G private network: For data security (kept on-site), assurance of E2E cloud collaboration capabilities and achieving intended high reliability and low latency requirements.	- AR virtual product design, workshop management, and remote expert consultation
- 5G enabled terminals from smart devices, AR glasses and cameras/HD cameras	- 5G slicing: public 5G network slice with E2E capability test of 5G slicing subscription among different applications on factory floor, warehouse floor, and wider campus.	- AR operation training eg identifying system parts and system module organisation training
- Factory components eg industrial cameras, vision processors, programmable logic controllers (PLCs)		- AR facial recognition for campus security purposes. Security guards patrol the campus with AR glasses to detect unauthorised presence in campus
- Dedicated AR application platform for design, inspection, maintenance, training processes	- MEC: MEC capabilities integrated into a single operation platform (COSMOPlat) including slice management capabilities to offer a single architecture for operational processes	- 5G AR glasses
- Localised cloud servers to carry AR computing power for local algorithm processing and on-site servers to ensure data security regulations.		

Exhibit 10. Case Study Haier – Summary

Source: Haier Unveils 5G-Empowered COSMOPlat at Hannover Messe, Illuminating the Future of the Industrial Internet

The key lesson from Haier's experience is that they led all efforts from the start, pushing its operators, infrastructure vendors alike to iteratively test 5G technical expertise aligned to operational needs. This reinforces the view that everyone is on a learning curve. As they started on the journey pre 5G standards, they have technical and basic business templates on the requirements to test 5G-enabled AR use cases. These should be made available to others to as to shrink development time.

3.2   5G-ENABLED AR ADOPTION CASE STUDY 2: MAZAK'S PROOF POINT FOR 5G[4]

Yamazaki Mazak is one of several test use case conducted under the umbrella of Worcestershire 5G Consortium between 2018 and 2020. They are testing the use of 5G to facilitate interactions during live streaming and communications between an expert and the remote field engineer.

Technology	5G configuration	5G AR test case
- To compare AR experience using 4G, private 4G, private 5G and WiFi LAN - Toshiba mobile PC connected to Toshiba AR headset with camera and small screen via USB-C. - Ubimax AR software solution.	- 5G NSA private network using Rel15 equipment only (Mar2018 – Mar2020 test period)	- AR-enabled remote expert access: AR solution with interactive live streaming and communication (verbal, visual & notations) between centrally located experts and field engineers distributed geographically dispersed areas. - Business case calculation for AR use case (remote expert): 5G NSA does not achieve meaningful savings (around 1-2% of productivity improvement) yet. - "None of the use cases considered by W5G would justify 5G investment in isolation. Multiple use cases, each delivering some commercial benefit, will likely be required to justify the move to 5G" Worcestershire 5G Testbed Final Report, Nov2020

Exhibit 11. Case Study Mazak – Summary

Source: Yamazaki Mazak Case Study - West Midlands 5G (wm5g.org.uk)

The key lesson from this case study is that the proof point to why we need 5G, specifically the full 5G capabilities in the form of 5G SA, is necessary to meet the baseline experience of 5G-enabled AR. This proof point is based on technical performance relative to 4G, 4G private networks, WiFi and 5G private networks. There is a need for the next releases of 3GPP to change the minds of not only the users but also C-level executives for releasing the investment. Waiting for the next releases also means there is a limit to the time in which the equipment will be ready, but AREA members should use this period to start educating enterprises, and the related ecosystem partners.

3.3   5G-ENABLED AR ADOPTION CASE STUDY 3: SAMSUNG ELECTRONICS AND MMWAVE IN THE US

Samsung Electronics and AT&T jointly ran a demonstration centre in the former's facilities to provide live experience of various 5G application, including robotics, IoT and mixed reality for training purposes. What is different in this case study is the local conditions in which 5G will be deployed in the US. The more common 5G flavour in the US is mmWave (See Essential 5G Glossary for definition), which runs on the high bands of 24.6GHz and above. This type of mmWave spectrum is currently released in the US but also in a selected number of countries such as Italy, Finland, Japan, and South Korea.

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[4] Case study https://www.wlep.co.uk/wp-content/uploads/W5G-Final-Report-Public-Release-1.pdf

Technology	5G configuration	5G AR test case
- To provide a hand-on demo area to explore new ideas over 5G and other complementary technologies eg multi-access edge computing - Microsoft Hololens headsets connected to 5G	- 5G Private networks using mmWave - Hybrid network of 5G, LTE, and WiFi - Multi-access edge computing	- Mixed reality for AR based remote repair: Workers rely on Microsoft Hololens to view instructions to troubleshoot and repair equipment. - Relies on 5G to support camera's video feed for latency and capacity to display the correct instruction at the right time and right worker.

Exhibit 12. Case Study Samsung Electronics – Summary

The key lesson from this case study is to highlight the importance of local conditions, with the simplest change being spectrum frequency. As mmWave spectrum is still being considered for allocation in the rest of the world, there is a need to ensure 5G-enabled AR use cases are conducted in localised areas because of spectrum availability. This reinforces the view that AREA members should engage with local companies, especially local testbeds, to be involved in the start of this journey.

4 CONCLUSIONS

The combined results of survey analysis and assessment of 5G-based enterprise AR projects provided some relevant insights for the enterprise AR community. Those results were discussed during a follow up webinar with the AREA members. This section will summarise some of those insights and ideas.

4.1 LESSONS LEARNED

The overall insights of the research can be encapsulated in the following 5 points:

1. 5G was seen as a key enabler of digital transformation in enterprises and of the overall Industry 4.0 paradigm.
2. However, 5G-enabled Industry 4.0 was in its early stage of development. There was time for a digital transformation strategy tuned also around 5G-AR.
3. AR within Industry 4.0 was not a unique priority and/or standalone technology for use cases. AR was part of a wider technology paradigm for Industry 4.0. The AR community should reflect on that, thinking at the convergence of AR with other Industry 4.0 enabling technologies.
4. The community should continue the effort in educating enterprises in the value and the benefits that AR can bring within digital transformation strategies. There was an absolute need to empower and diffuse the culture of enterprise AR.
5. There were some organisations outside the typical AR community that strongly believe in AR. Those should have become AR champions in enterprises.

The world of 5G in enterprises is moving rapidly enabling further sophistication in the Industry 4.0 paradigm. The enterprise AR community is increasingly part of it, but more can be done.

5 FURTHER RESEARCH

Through AREA, the AR ecosystem is developing knowledge about their relationships with emerging technologies. A previous study on the convergence between the IoT and AI, always sponsored by AREA, provoked a lot of discussions within the community as the one on 5G. However, the pace of technological development in those areas is rapid. Therefore, an area of further research discussed was to develop a methodology able to update the AREA members on the evolution of those technologies, on the impact on management and business models and effects on the market. The idea discussed was then to define an Observatory for Emerging Technologies that could also be able to provoke skilling and training initiatives.

The proposal for an Observatory of Emerging Technologies remains valid today. Since the end of the project in September 2021, there has been an acceleration in the discussion on the relationship between technologies and sustainability, and enterprises and sustainability. The new term "Industry 5.0" is starting to substitute the "Industry 4.0". As stated by the European Commission, "*Industry 5.0 complements the existing "Industry 4.0" approach by specifically putting research and innovation at the service of the transition to a **sustainable, human-centric** and **resilient European industry**"*. [5] **Therefore, which is the role of enterprise AR in that?**

6 ACKNOWLEDGMENT

It is always important to praise who believes in research as an essential tool for decision making. This is the case of Christine Perey and Mark Sage, who together animate and support the hectic community of enterprise AR professionals and companies under the umbrella of AREA. I want to thank Christine and Mark for supporting my research on the convergence of AR with other emerging digital technology frameworks. I also want to thank the AREA members who have provided critical and insightful responses to the research.

7 REFERENCES

AT&T Foundry. 2017. Enabling Virtual and Augmented Reality through 5G Networks

Gary White, Christian Cabrera, Andrei Palade, Siobhan Clarke. 2018. *Augmented Reality in the IoT.* https://www.researchgate.net/publication/327884565_Augmented_Reality_in_IoT

Swarup Mitra. *The Role of Augmented Reality and IoT in the Connected Digital Enterprise.* https://www.tcs.com/blogs/the-role-of-augmented-reality-and-iot-in-the-connected-digital-enterprise

Helen Papagiannis. *Augmented Human.* https://www.augmentedhuman.co/

S.K. Ong, M.L. Yuan and A.Y.C. Nee. *Augmented reality applications in manufacturing: a survey.* https://www.tandfonline.com/doi/full/10.1080/00207540601064773?scroll=top&needAccess=true (accessed with OpenAthens)

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[5] *Industry 5.0 (europa.eu)*

D.W.F. van Krevelen and R. Poelman. *A survey of Augmented Reality technologies, applications and limitations.* https://www.researchgate.net/profile/Rick_Van_Krevelen2/publication/292150312_Augmented_Reality_Technologies_Applications_and_Limitations/links/56ab2b4108aed5a01359c113/Augmented-Reality-Technologies-Applications-and-Limitations.pdf

Cognizant. *Augmented Reality & Business: Bridging Virtual & Physical Gaps.* https://www.cognizant.com/whitepapers/augmented-reality-and-business-bridging-virtual-and-physical-gaps-codex2922.pdf

Garcia, G. et al. *A Review of Artificial Intelligence in the Internet of Things.* University On-line Libraries

Potter, M. and Heppelman, J. *Why Every Organisations Needs and Augmented Reality Strategy.* University On-line Libraries

Dongsik, J and Kim, G. *ARIoT: scalable augmented reality framework for interacting with Internet of Things appliances everywhere.* University Library - IEEE Transactions on Consumer Electronics

Qualcomm. *5G and AR. https://www.qualcomm.com/media/documents/files/vr-and-ar-pushing-connectivity-limits.pdf*

PTC and ABI Research. *The Power of IoT Platforms for Building AR Applications.* https://www.ptc.com/en/resources/iot/white-paper/iot-platforms-ar-apps

Masoni, R. et al. Supporting remote maintenance in industry 4.0 through augmented reality. *https://pdf.sciencedirectassets.com/*

Deac, C.N. et al. *Using Augmented Reality in Smart Manufacturing.* file:///C:/Users/saver/AppData/Local/Packages/Microsoft.MicrosoftEdge_8wekyb3d8bbwe/TempState/Downloads/Using_Augmented_Reality_in_Smart_Manufacturing%20(1).pdf

De Pace et al. *Augmented Reality in Industry 4.0. Ameican Journal of Computer Science and Information Technology* (http://www.imedpub.com/articles/augmented-reality-in-industry-40.php?aid=22168)

Zhang, Y. et al. *Design and Interaction Interface using Augmented Reality for Smart Manufacturing.* Procedia Manufacturing (https://www.sciencedirect.com/science/article/pii/S2351978918308163)

Fraga-Lamas, P. et al. *A Review on Industrial Augmented Reality Systems for the Industry 4.0 Shipyard.* https://ieeexplore.ieee.org/document/8298525

Siemens White Paper. *Augmented Reality - marketing gimmick or real-world potential?* https://new.siemens.com/global/en/products/automation/topic-areas/tia/future-of-automation/whitepaper-augmented-reality.html

Siemens White Paper. White paper. *Artificial Intelligence: The next digital horizon.* https://new.siemens.com/global/en/products/automation/topic-areas/tia/future-of-automation/whitepaper-shopfloor-ai.html

Minsait. *Advanced manufacturing, beyond Industry 4.0.* https://www.minsait.com/sites/default/files/newsroom_documents/advanced_manufacturing_beyond_industry_4.pdf

Institute of Creative Media Technologies, St. Polten University of Applied Sciences, Austria. *Scientific paper: Augmented Reality for Industry 4.0: Architecture and User Experience.* http://ceur-ws.org/Vol-2299/paper5.pdf

PwC. *Industry 4.0: Building the digital enterprise.* https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

Ian Wright. *What Can Augmented Reality Do for Manufacturing?* https://www.engineering.com/AdvancedManufacturing/ArticleID/14904/What-Can-Augmented-Reality-Do-

for-Manufacturing.aspx

George Kollias. *Remote AR Assistance: 9 most trusted solutions in the Industrial Manufacturing Sector.* https://medium.com/smarterchains/remote-ar-assistance-9-most-trusted-solutions-in-the-industrial-manufacturing-sector-265a8efce137

Magid Abraham, Marco Annunziata. *Augmented Reality Is Already Improving Worker Performance.* https://hbr.org/2017/03/augmented-reality-is-already-improving-worker-performance

Jason Orlosky et al. 2017. *Virtual and Augmented Reality on 5G Highway*. Journal of Information Processing, Vol.25

8   ESSENTIAL 5G GLOSSARY

5G – SA (5G Stand Alone): NSA 5G NR enables the deployment of new 5G cells and the use of the new 5G frequencies leveraging the current LTE infrastructure.

5G- NSA (5G Non Stand Alone): SA 5G NR enables the deployment of 5G based on the next-generation core network architecture, independently from the LTE infrastructure.

IoT (Internet of Things): 5G deployment dedicated to one or more IoT applications

MEC (Mobile Edge Computing): Deploying cloud-computing capabilities within the radio access network, implementing additional computing, storage and networking resources at the cellular base stations or other edge nodes

ML/AI (Machine Learning/Artificial Intelligence): 5G deployment dedicated to one or more ML/AI applications.

mmWave (millimeter Wave): Within a 5G context, mmWave indicates the use of frequency bands between 24 and 100 GHz. That means much larger bandwidth than lower frequencies, resulting in increased network capacity and data rates.

Private network: Local network within a company or any other organisation, usually dedicated to specific applications.

Slicing or network slicing: It creates multiple virtual networks (called network slices) on top of a shared physical network infrastructure. Each network slice, represents an independent end-to-end logical network that can be fully configured, managed and operated independently.

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