6G WAVES
MAGAZINE

6G
FLAGSHIP
UNIVERSITY OF OULU

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Research Council of Finland

FLAGSHIP PROGRAMME

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FOREWORD

6G is on the horizon, with the industry becoming seriously involved. There's a lot of discussion and debate, particularly around whether 6G should be an evolutionary step from 5G or a radical departure towards something new. This debate is largely driven by the fact that the monetisation of 5G is still an ongoing process, leading to many questions about the next steps in wireless technology development.

At the time of printing this magazine, the World Radiocommunication Conference 2023 (WRC'23) is taking place in Dubai. A key topic of discussion there is the utilisation of the 7-15GHz band, known as FR3, as the main spectrum for 6G. This is expected to rejuvenate research in dynamic spectrum-sharing, now enhanced with AI and machine learning to make it more effective. However, reaching a consensus is challenging, especially with the diverse views and complex situations involving primary users, such as those in Europe's defence sectors.

In the current geopolitical climate, the resilience of 6G technology is becoming increasingly important. Many countries are focusing on dual-use capabilities. The International Telecommunication Union-Radiocommunication Sector (ITU-R) has proposed ubiquitous connectivity as a new usage scenario for 6G. This raises important questions: What implications does this target have? Will satellite technology finally be integrated into the overall 6G architecture?

Research into combined communications and sensing, bolstered by AI, is at the forefront of forging new directions for the future. While the journey of 6G research is laden with challenges, we are beginning to see promising land on the horizon. As we steer through these waters, it's our hope that the global 6G fleet will also perceive this same destination and steadily set their course towards it. The 6G Flagship is committed to leading the way in this endeavour.

Matti Latva-aho

Director of 6G Flagship
University of Oulu, Finland

RIS FOR 6G

MARKKU JUNTTI'S VISION FOR THE FUTURE OF COMMUNICATION

As the adoption of 5G networks expands, attention is increasingly turning to the capabilities of 6G technology, particularly in the area of smart channel control. Pioneering this field is Professor Markku Juntti of the University of Oulu's 6G Flagship. In his 6G Talk, Juntti highlighted the role of Reconfigurable Intelligent Surfaces (RIS) as a key innovation that could alter the future of wireless communication.

RIS – Intelligent Channel Manipulation

RIS, also known as intelligent reflecting surface (IRS), is a programmable reflecting surface capable of adjusting the reflection of electromagnetic waves. This allows for applications such as beam steering to meet specific network performance objectives.

The foundational idea of RIS is derived from the Large Intelligent Surface (LIS) concept, which involves positioning a reflector close to the transmitter or receiver to create a large virtual antenna array. This concept was soon extended to allow RIS to be positioned further away, thereby offering more flexibility for channel manipulation, including the avoidance of line-of-sight obstacles. Philosophically, RIS was considered as part of the channel leaving the transmitter and receiver design largely intact.

RIS and AI Integration

Controlling the reflecting surfaces, i.e., making them truly intelligent, is complex due to the multitude of tunable elements involved. To optimise their performance, machine

learning (ML) or artificial intelligence (AI) can be valuable. When integrated with ML, RIS supports a range of advanced applications such as real-time translation, holographic communication, and autonomous vehicles. Researchers at the University of Oulu and the 6G Flagship have been addressing these complexities within the framework of the EU-funded ARIADNE project from 2019 to 2023.

Channel Estimation and Positioning

RIS can function as an auxiliary component in wireless systems, similar to network repeaters or relays. This perspective enables the calculation of signal paths between the transmitter and RIS and then from RIS to the receiver. Such calculations can enhance beamforming, resource allocation, and even mobile positioning. However, implementing this approach demands resource-intensive algorithms and substantial channel training.

Practical Alternatives for Channel Estimation

For pragmatic purposes, simpler methods of channel estimation are often more suitable. One approach is to equip the RIS with an active receiver, simplifying the task of measuring component channels. Although this adds a layer of complexity to RIS implementation, it also distinguishes RIS as a separate network element.

RIS and Relay

RIS shares conceptual similarities with active relay stations. A hybrid structure has also been explored, substituting some of the passive reflective surface elements with amplified reflective elements. This hybrid approach allows for greater control over beamforming, thereby enhancing the overall link budget.

Outlook

Environmental considerations are paramount for the development of 6G networks. The efficient deployment of technologies like RIS, which are inherently low in power consumption, is integral to achieving energy-efficient systems. Alongside these benefits, current research is investigating how RIS can improve both security and privacy, as well as contribute to integrated sensing and communications (ISAC).

Watch Markku's 6G Talk:
youtu.be/BJDKsj155BE

ADVANCEMENTS IN
WEARABLE SENSING

PIONEERING WIRELESS TECHNOLOGY

In the dynamic landscape of wireless technology, wearable sensing devices have surfaced as critical instruments in observing human health and well-being. The potential these devices hold to transform healthcare through real-time data acquisition and analysis for individualised diagnostics and treatment is substantial. The University of Oulu's Microelectronics Research Unit stands at the vanguard of this transformative research, relentlessly exploring the edges of technological capabilities.

In a 6G Talk, Adjunct Professor **Jari Hannu** highlighted the strides made in wearable sensing. The primary focus is the development of materials and structures that facilitate the effortless integration of sensors into wearable devices. The goal remains to fabricate devices that exhibit flexibility, washability, and comfort for prolonged wear.

A significant breakthrough is the development of highly stretchable resistive sensors, competent in accurately measuring a range of physiological indicators, including breathing rate, pulse levels, and vocal vibrations. Through the innovative use of carbon materials obtained from nature and composite structures, sensors capable of measuring stretch and pressure have been realised. This pioneering

discovery paves the way for wearable devices with a plethora of potential applications.

The unit is tackling the challenge of sensor integration into clothing. Progress thus far has led to the creation machine washable sensors operating on resistive sensing mechanisms. These sensors can measure pressures, vibrations, and strains, providing valuable insights into body movements and physical activities. The focus is on making the sensors as durable and practical as possible, opening the path for greater utilisation of wearable technology in sports, healthcare, and industrial safety.

The research encompasses temperature sensing, with the development of stretchable sensors that can be comfortably applied to the skin. This inventive approach allows for precise skin temperature measurement, even during stretching, facilitating extensive monitoring of physiological changes. Investigations into self-healing materials and flexible, stretchable transistors are ongoing to enhance wearable devices' durability and lifespan.

This groundbreaking research has thrived on collaborative efforts and exploring of materials derived from biological sources. Using lightweight carbon nanocomposites and biodegradable carbon materials, the Microelectronics Research Unit has achieved effective shielding against radio frequency signals, which can be used to bolster privacy and security in wireless communication.

A significant breakthrough is the development of highly stretchable resistive sensors, competent in accurately measuring a range of physiological indicators, including breathing rate, pulse levels, and vocal vibrations.

In a commitment to innovation, new applications for wearable sensing devices are being explored. Given the backdrop of the COVID-19 pandemic, smart masks with integrated commercial sensors have been developed. These sophisticated masks can monitor factors like carbon dioxide levels and temperature while ensuring optimal fit and comfort. It's projected that these smart masks could significantly bolster public health and safety in the future.

The research aspires to develop materials capable of changing shape, size, and colour in response to environmental conditions. This futuristic vision, reminiscent of science fiction, may lead to the creation of personalised and adaptable environments. Despite the inherent challenges, the potential rewards fuel motivation.

The Microelectronics Research Unit is committed to discovering new materials, structures, and functionalities to push wearable sensing technologies forward. In doing so, it seeks to fully harness the potential of wireless technology and its influence on various life aspects. The emphasis remains on leading research in wearable sensing for healthcare and personal well-being.

Watch Jari's 6G Talk: :
youtu.be/s66tA-2g1TE

MICROWAVE COMPOSITES

AND THE COMMUNICATION REVOLUTION

Microwave composites, while technical in nature, hold significant implications for the future of communication. Dr Sami Myllymäki's recent 6G Talk sheds light on these materials' pivotal role as we transition towards advanced telecommunication systems. Here's an exploration of his insights.

More Than Just Tech Jargon

Microwave composites are at the heart of the next-gen communication systems, especially as we edge towards 6G. These aren't mere buzzwords but the foundation of future telecommunication devices. Their unique properties make them indispensable for enhancing signal transmission, reducing energy losses, and ensuring that devices can handle the demands of higher data transfer rates. Dr Myllymäki's insights emphasise that as we demand more from our communication devices regarding speed, efficiency, and connectivity, the role of microwave composites will only grow in importance.

Dielectric Materials: The Unsung Heroes

Dielectric materials serve as the unsung heroes in the realm of microwave composites. These specialised insulators have the unique ability to undergo polarisation when exposed to an electric field. This polarisation process is crucial because it determines how the material will interact with electromagnetic waves, especially at high frequencies.

The measure of a dielectric material's ability to store energy in an electric field is termed its permittivity. In the world of telecommunications, where signals are transmitted at incredibly high frequencies, the permittivity of materials becomes a pivotal factor. It influences the speed, efficiency, and clarity of signal transmission.

Not all dielectric materials are created equal. Each material possesses different permittivity levels, challenging re-

searchers like Myllymäki to identify those that strike the perfect balance. The right dielectric material can make the difference between a clear, rapid communication and a lagging, distorted one.

As we venture further into the era of 6G and beyond, the quest for the perfect dielectric material becomes even more pressing.

Navigating the Challenges

While the potential of dielectric materials in advancing communication technology is undeniable, the path to optimisation is riddled with intricate challenges. One of the primary concerns is the inherent energy losses during polarisation. These losses, though minuscule at first glance, can have cascading effects on the efficiency of communication devices.

But it's not just about energy losses. The synthesis of new materials, like the PMMA polymer barium titanate or nanocellulose composites, brings its own set of challenges. Ensuring consistent material properties, scalability for industrial production, and long-term stability are all areas that researchers grapple with. Moreover, as devices become smaller and more integrated, their materials need to be adaptable without compromising on their core properties.

For researchers like Dr Myllymäki, it's a delicate dance of pushing the boundaries of what's possible while ensuring reliability and efficiency. It's this intricate balance that will determine the pace at which we move towards a 6G future.

Horizon of Possibilities

As we stand on the cusp of a new era in communication, the work of experts like Dr Myllymäki becomes increasingly pivotal. Microwave composites aren't just about faster data rates or clearer calls; they represent a leap towards a world where technology seamlessly integrates with every aspect of our lives. From smart cities to remote surgeries, the potential applications are vast and transformative.

6G is not just another upgrade; it's a paradigm shift. And with the relentless pursuit of researchers and the promise of materials like microwave composites, we're not just looking at the next step in communication – we're envisioning a future where boundaries are redefined, and the unimaginable becomes a reality.

Watch Sami's 6G Talk:
youtu.be/ASs2M-2bOKE

HARNESSING
ENERGY
EFFICIENCY
FOR A SUSTAINABLE FUTURE

Eva Pongracz, a luminary in sustainability, shed light on the intricate role of energy in sustainable development. The concept is defined: "Sustainable development is development that meets the needs of the present, but without compromising the ability of future generations to meet their own needs." While this perspective is widely accepted, it has faced scrutiny for not setting clear boundaries on economic growth and its somewhat veiled stance on environmental matters.

Addressing these concerns, Pongracz painted a comprehensive picture, juxtaposing human needs against those of ecosystems. She charted a hierarchy of human necessities, ranging from fundamental physiological requirements to loftier societal aspirations. Conversely, she underscored the imperatives of ecosystems, highlighting essentials such as sunlight, water, and biodiversity.

The Challenge of Energy in Sustainability

Emphasising the pivotal role of energy in achieving sustainability, Pongracz aptly stated, "All of this requires energy. Every system, industry sector, and service depends on it to operate." This statement gains even more significance when contemplating the staggering number of individuals worldwide who still lack reliable access to adequate energy sources, underscoring the urgent need for equitable energy distribution and accessibility.

She explored the concept of 'planetary overshoot', a measure that reflects our rate of consuming a year's worth of resources. Disturbingly, Pongracz emphasised that for over fifty years, we have been operating at a deficit, consuming more than the planet can replenish, all while the global population continues to grow. This stark reality accentuates the urgency for our consumption patterns to evolve towards sustainability.

Digitally-Enabled Systems: A Path to Sustainable Behaviour

Venturing into digital systems, Pongracz explored their potential in steering human behaviour towards sustainability. She contended that such systems should not merely cater to user preferences but actively promote sustainable actions. The longevity of the components in these systems, coupled with opportunities for upgrades or repurposing, was another focal point of her talk.

Pongracz's insights were a profound exploration into the multifaceted world of sustainability and energy efficiency. Her discourse underscored the imperative of a harmonised approach that weighs both human and ecosystem needs in equal measure. Moreover, she spotlighted the transformative potential of digitally-enabled systems in fostering sustainable behaviours, laying the groundwork for a greener future.

As the horizons of 6G technology expand, Pongracz's insights emerge as a beacon. They underscore the symbiotic relationship between technological progression, sustainability, and energy efficiency. As we navigate this journey, her wisdom serves as a compass, guiding us towards a future that seamlessly melds technological prowess with sustainability and equity. She concluded with a powerful reminder, "Sustainability as a concept is an absolute, which means it's indivisible. You cannot be almost sustainable. If we are sustainable, it means everybody everywhere is sustainable."

Watch Eva's 6GESS Talk:
youtu.be/0HoEYU1kSao

ASSOCIATE PROFESSOR
MEHDI RASTI

ADVANCING WIRELESS COMMUNICATION AND 6G TECHNOLOGY FOR A
SUSTAINABLE FUTURE

Dr Mehdi Rasti is an experienced scholar and educator working as an Associate Professor at the University of Oulu's Centre for Wireless Communications. Rasti has held various academic and research posts throughout the years, expanding his wireless communication and network optimisation knowledge and abilities.

His interest in the topic was motivated by his curiosity about the extraordinary capabilities of wireless communication.

This interest led him to a career in academia. He served as Research and Technology Deputy of the Department of Computer Engineering and IT, director of international cooperation, head of the ICT Research Centre, and president of the Kish-International Campus at Amirkabir University of Technology in Tehran, Iran. Through these experiences, Rasti has developed a robust skillset in leadership, international cooperation, and entrepreneurship. He believes these skills will continue to benefit him in his current and future endeavours.

From Early Experiences to Professional Pursuits

"My initial exposure to signal transmission and communication came from using old-fashioned landline phones and watching television in childhood. During the 1994 World Cup, as a 15-year-old boy, I recall wondering how the final match between Italy and Brazil in the United States could be viewed live at my house! At the time, the only explanation I could make was based on my firsthand experience with sound reflection while mountain climbing in my hometown, where I had encountered fascinating multiple echoes."

> *Critical research questions for advancing the field of 6G and positioning it as a catalyst for sustainable economic growth.*

As Rasti contemplated his potential career paths, he reflected on childhood memories. Of all the options in engineering — mechanical, electrical, civil, chemical and materials — electrical engineering and communication systems was the direction that resonated with him most significantly.

"I felt that the services and products in this field were unique and unparalleled, unlike other fields of study. For instance, the concept of the wheel likely emerged when primitive humans observed a round object rolling on the ground. The idea of constructing a bridge might have originated from witnessing a fallen tree spanning a river." I struggled to find any natural phenomenon corresponding to the real-time transmission of sound, images, and video over long distances. This aspect of wireless communication appeared incredibly surprising and inventive to me. It propelled me onto the path of becoming a wireless communications researcher. To this day, I am still in awe of this area and its enchantment," Rasti exclaims.

An Impactful Research Career

Throughout his career, Rasti has made significant contributions to the wireless communication domain. His research interests include radio resource allocation in 5G/beyond 5G and 6G wireless networks, the application of machine learning and optimisation methods, and cyber-physical systems for specific verticals such as the energy sector.

Successfully securing funding for his research proposals, Rasti has obtained support for both the "Local 6G" project and the "Reliable 6G for Energy Vertical" project in consortium with VTT and LUT. Business Finland provided the funding for these projects in 2023.

Building Collaborations and Advancing Research

Rasti highlights the value of networking and engagement with national and international partners to expand his research team and advance his work. He has had several funded research visits in KTH, Sweden, in 2007; the University of Manitoba, Canada, in 2013 and 2014; and LUT, Finland, in 2021.

"For me, the most valuable aspect of these collaborations has been the opportunity to learn from and share knowledge with colleagues who bring diverse perspectives and skill sets to the table," explains Rasti. "My philosophy is based on the idea of "networking or not working" because I truly believe that collaboration is key to advancing research. We have built a strong network of support and expertise that extends far beyond the walls of our own institution."

One of Dr Rasti's primary research focuses is on developing and deploying 6G in a way that promotes sustainability in various industries. Investigating the specific needs of diverse verticals, such as energy systems, and deciding how 6G technology may be used to meet those demands, according to Rasti, are "critical research questions for advancing the field of 6G and positioning it as a catalyst for sustainable economic growth."

Notable Publications and Impact on the Field

Dr Rasti has over 40 conference papers and 40 journal papers published in highly scholarly IEEE Conferences and Journals during the last 14 years. He has been Thesis Supervisor/Co-Supervisor for 9 PhD students and over 25 MSc students. His paper on the evolution toward 5G multi-tier cellular wireless networks, published in IEEE Communications Letters in 2014, has been among the top 10 articles published in IEEE ComSoc periodicals viewed online. His co-authored textbook, "Radio Resource Allocation in Wireless Networks: An Engineering Approach," published by the Cambridge University Press in 2017, further highlights his contributions to the field.

Associate Professor Mehdi Rasti's dedication to advancing wireless communication and 6G technology has made a significant impact on the field. His passion for research and collaboration and his commitment to sustainability and innovation continue to inspire the next generation of researchers and drive progress in wireless communication.

Read more:
6gflagship.com/news/green-energy-and-industrial-innovation-powered-by-6g/

PROFESSOR MATTI LATVA-AHO AWARDED PRESTIGIOUS

IEEE FELLOW HONOUR

In a significant recognition of his contributions to the field of mobile communication systems, Professor Matti Latva-aho, Director of 6G Flagship, has been elevated to the esteemed rank of IEEE Fellow. The announcement, made by the IEEE Board of Directors in their November 2023 meeting, places Latva-aho among the top echelons of the global technology community. This elevation, effective from 1 January 2024, is a testament to his distinguished career and impact in the domain of mobile communications.

The IEEE bestows the prestigious Fellow designation on fewer than 0.1% of its voting members each year through a rigorous evaluation, marking it as a highly esteemed honour by the leading global association for technological advancement.

Throughout his career at the University of Oulu, Latva-aho has been a guiding force in wireless communications research. Beginning his tenure at the University of Oulu in the early 1990s, Latva-aho advanced to become a professor of communications engineering in 2000. Additionally, he served as the director of the Centre for Wireless Communications (CWC) from 1998 to 2006. From 2017 to 2021, he held the position of Academy Professor, and since 2018, he has been the Director of the National 6G Flagship, with a budget of 251 million euros.

Professor Latva-aho's 653 published works have garnered 12,819 citations, evidencing his impact in academic research. Furthermore, he has actively supervised 31 doctoral candidates from 2003 to 2019, with 10 earning distinctions for their exceptional theses.

"Receiving this honour from IEEE is deeply humbling. It represents not just a personal achievement but the culmination of decades of research in wireless communications. Our journey at the University of Oulu, especially in exploring new spectrum allocations and enhancing wireless network capacities, is about pushing the frontiers of technology for societal benefit," Latva-aho reflects.
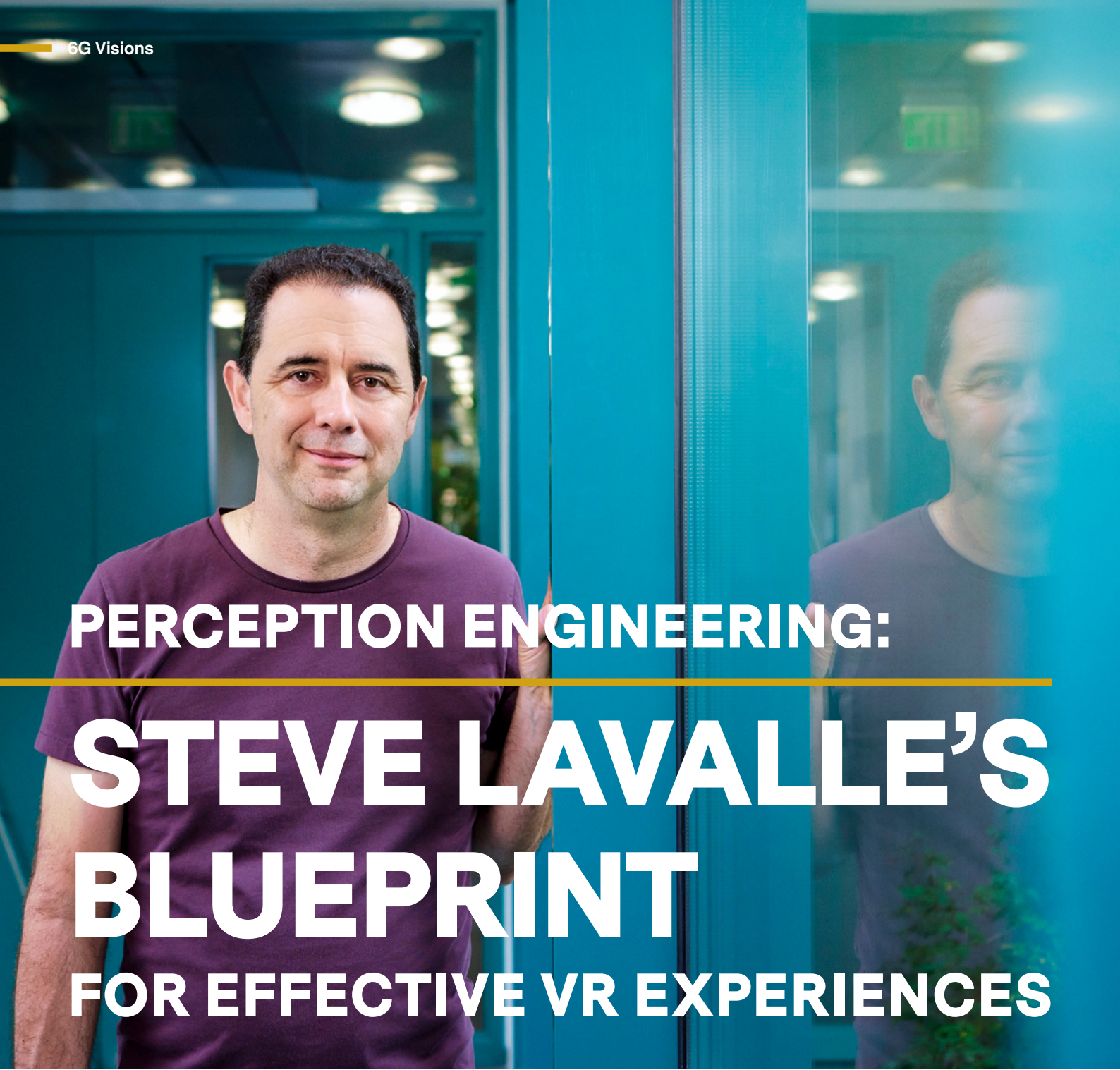
Latva-aho's commitment to exploring the future of wireless systems, from transmission technologies to receiver architectures, continues to inspire and guide the next generation of researchers and technologists, further cementing the university's reputation as a hub of innovation and technological advancement.

Read more:
6gflagship.com/news/academy-professor-matti-latva-aho-is-a-veteran-of-all-the-gs

PERCEPTION ENGINEERING:

STEVE LAVALLE'S BLUEPRINT FOR EFFECTIVE VR EXPERIENCES

In Irvine, a hub of technological innovation, Professor Steven LaValle carved a niche as one of the masterminds behind Oculus VR. It was a game-changer that Facebook couldn't resist snapping back in 2014. But while many would have been content basking in the afterglow of such a monumental acquisition, LaValle had other plans. He left his established home in Illinois to join the vibrant academic community at the University of Oulu in Finland.

For LaValle, the glimmer of Silicon Valley's tech scene pales in comparison to the pursuit of genuine scientific understanding. He's seen the future, and it's not just about strapping on a headset and escaping reality. It's about grounding virtual reality in solid academic research, ensuring it's more than another fleeting tech trend. In Oulu, he's championing this cause, advocating for a robust theoretical foundation for virtual reality. It's a mission that might lack the glamour of billion-dollar buyouts, but in LaValle's eyes, it's the next frontier.

The Potential of Perception Engineering

The VR industry has seen its share of highs and lows. From the rudimentary VR glasses of the 1960s to today's sophisticated devices, the journey has been marked by innovation and disillusionment. LaValle recalls past ventures like the Nintendo Virtual Boy, which highlights the pitfalls of prioritising novelty over depth. The hype and excitement for VR products often gets ahead of the true market demand," he observes.

While LaValle acknowledges the undeniable allure of virtual reality, particularly its promise to transport users to alternate realms, he advocates for more. With his unique blend of industry and academic insight, he calls for a deeper, more scientific approach to VR. It's not enough for VR to be immersive; it must be rooted in a profound understanding of how humans perceive and interact with these digital realms. The current trajectory, he suggests, is one of surface-level fascination. For VR to truly revolutionise, LaValle and his team believe it must transcend the superficial and venture into genuine scientific inquiry and understanding.

LaValle isn't just pointing out the gaps; he's envisioning the future. With the support of significant ERC funding for his 5-year ILLUSIVE project, which began in 2021, LaValle and his team have already made substantial strides in laying the groundwork for the revolution in a field he coined 'perception engineering'. "The next leap of VR innovation will be deeply rooted in the fusion of psychology, neuroscience, and physiology," LaValle predicts. By embracing this multi-faceted approach, upcoming VR technologies will resonate more naturally with human cognition, offering richer and more genuine experiences. At the University of Oulu, LaValle is championing this cross-disciplinary collaboration, helping set the stage for VR's transformative era.

A Reality Check for the VR Industry

While many are captivated by the allure of the latest gadgets and innovations, LaValle provides a tempered perspective. In his view, "artificial industry lacks scientific foundation." He does not say this as a mere critique but as a call to action born from years of hands-on experience and scholarly depth.

LaValle warns against the race for eye-catching yet superficial VR experiences. He urges the industry to move beyond the 'shiny object syndrome' and focus on the intricate relationship between human perception and technology. This is where his concept of perception engineering becomes pivotal.

The Intellectual Vanguard of VR's Future

In the relentless race of tech innovation, it's not enough to be a trailblazer; we need scholars with grit. Steve LaValle is that rare blend. He doesn't just question the status quo; he upends it. And as the boundaries between the real and the virtual become increasingly porous, LaValle's message is clear: The future of VR isn't just in the hands of its creators but in the minds willing to dive deep. To the next generation of VR pioneers: The depth of your dive will define the impact of your innovation.

6G IS THE ENABLER FOR
METAVERSE

In an era marked by unprecedented technological progression, the Metaverse emerges as a pivotal innovation set to pervade all forms of business, trade, and industry, as well as the daily lives of individuals. The Finnish Metaverse ecosystem is the first in Europe to create a Metaverse Initiative, and one of the first ones globally. The objective is to play a key role in shaping the future of digital experiences, focusing on developing the Metaverse ethically and responsibly. This includes prioritizing privacy, user safety, and considering its overall societal impact.

The Fourth Industrial Revolution is reshaping our approach to work and value creation. Just as mobile phones, PCs, and the Internet heralded new digitalization waves, the Metaverse is poised to do the same, offering vast potential to transform our interactions and engagement with the surrounding world.

Leveraging its rich heritage in innovation, robust technology infrastructure, and proficiency in new technologies, Finland has a pioneering role in Europe. Business Finland initiated a process, which culminated in the launch of the "Metaverse Initiative by Finnish Ecosystem" at the Match XR event in Helsinki at the wake of Slush 2023.

The initiative was created in close cooperation with 400+ members of the Finnish ecosystem and some of the strongest Finnish large and SME companies, including major players like Nokia, KONE, Varjo, and Dispelix. The industry in Finland is projected to achieve a €30 billion volume by 2035, supported by an ecosystem estimated to encompass over 250 companies. Researchers from the University of Oulu have been involved in the process in many ways.

The world is changing rapidly in many ways, and the Metaverse will challenge the requirements of wireless communications, mostly from connectivity. Our future society is data-driven, enabled by near-instant and unlimited wireless connectivity. 6G networks and technology play a key role in this development. We need speed, capacity, reliability, low latency to enable the visions to come true. Finland has been the first in 6G and with the launch of this initiative it wants to takea leading position in the Metaverse discussions, too.

"The metaverse is a new dimension of the internet, and we need a strategy that reflects its potential and diversity. We are looking for partners who share our vision and want to create a metaverse strategy that is harmonious and impactful. Together, we can build a better digital world for everyone.", continues **Jani Vallirinne**, Metaverse Strategy Lead, University of Oulu and VTT Technical Research Centre of Finland.

The Metaverse presents substantial business potential, fostering innovation, growth, and new revenue streams across industries. Particularly, sectors like gaming, e-commerce, and advertising stand to gain immensely thanks to new monetization models and marketing opportunities. This digital frontier blurs the lines between physical and digital experiences, creating new business models and value propositions.

"The Metaverse is still more of a vision than reality as significant steps will be required in technology, standardization, usability, business, regulation, and content development. Finland wants to become an inspiring role model for the whole world. We want to ensure that the Metaverse has open standards and interfaces that provide sufficient independence and freedom and protect the ecosystem from being dominated by a single company or country," says **Jani Jokitalo**, Account Manager, ICT and Digitalization at Business Finland.

Watch the Metaverse Initiative launch at
youtu.be/xDEneVva1bM?t=232

Join Metaverse in Action Programs at
digitalfinland.org
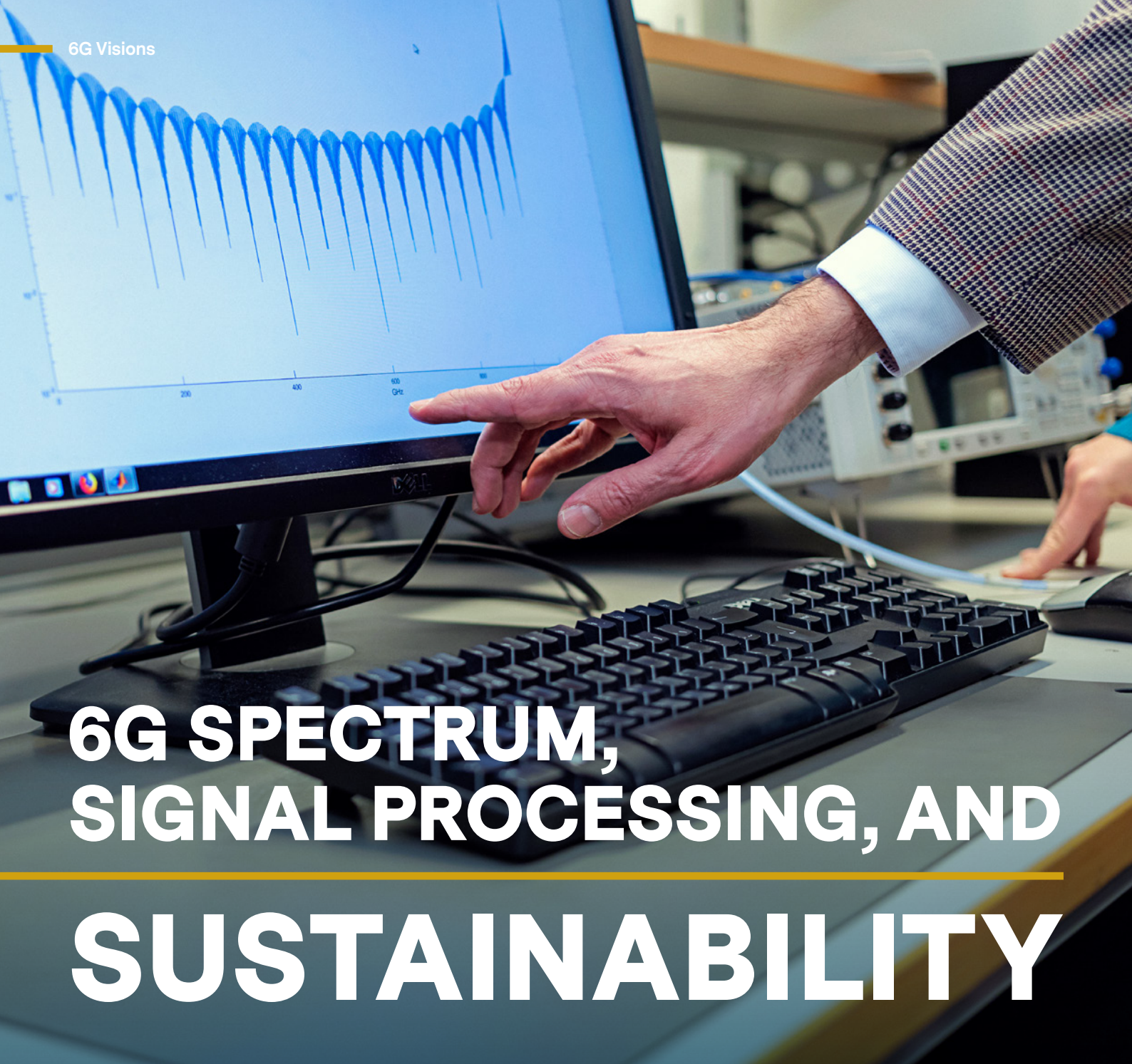
6G SPECTRUM, SIGNAL PROCESSING, AND

SUSTAINABILITY

The number of antennas in communication devices is growing steadily, especially as we advance toward higher frequencies used by 6G systems. This increase in antennas poses both technological and economic challenges that must be addressed. 6G Waves talked with Professor Antti Tölli about the situation.

Signal Processing and Efficiency

"Increasing the carrier frequency tenfold opens the possibility of housing up to 100 antennas in the same space that once accommodated just four. This is not a mere numerical upgrade; it transforms the multi-antenna signal processing landscape," Tölli explains. With signals travelling at the speed of light, the implications for wavelength and antenna element dimensions are profound, emphasising the need for

sophisticated processing techniques as signal power density decreases with distance.

Within this context, digital beamforming plays a pivotal role. "Through precise mathematical operations in the transmitter-receiver chain, we can target signals not only in general directions but focus them towards specific users, thereby serving multiple clients simultaneously without causing too much interference," continues Tölli. "This more sophisticated beamforming approach allows for a significant reduction in power wastage."

The Challenge of Channel Information

"As we integrate more antennas and serve a higher number of users, it becomes challenging to collect precise channel in-

formation," observes Tölli. He proposes machine learning as a viable approach, suggesting, "Machine learning's increasing relevance across engineering disciplines is becoming evident as it enters signal processing research. It can enable us to glean real-time data and forecast future channel conditions, lending remarkable adaptability to the system."

> ## *Improving energy efficiency is not just beneficial but essential.*

Environmental Considerations

"The environmental impact of the ICT sector's advances is undeniable," Tölli states. "It accounts for a considerable percentage of the world's electricity consumption and greenhouse gas emissions, driven largely by the prevalence of wireless networks and social media applications." He underscores the pressing need for sustainable practices within the industry. With the increasing demand for high-speed data transfers, "improving energy efficiency is not just beneficial but essential," argues Tölli, stressing the importance of targeted research to lessen the environmental impact.

Applications, Safety, and Coded Caching in Virtual Environments

Professor Tölli champions an integrated approach to signal processing that prioritises both efficiency and safety. He stresses the importance of regulating electromagnetic radiation levels, particularly in densely populated areas. "Managing radiation is not a matter of theoretical debate but practical safety. Digital beamforming can help us to control radiation exposure around antennas, keeping it within safe thresholds," Tölli emphasises. He further notes that advancements in multi-antenna signal processing are crucial to mitigating the potential fallibility of hardware components, thereby bolstering the reliability and security of communication systems.

Additionally, Tölli addresses the growing capabilities of devices in handling data, especially in the context of virtual environments. "The increasing memory capacity of modern devices allows for the strategic storage of location-dependent data. This can be adeptly coded to improve data transmission efficiency, serving multiple users more effectively, a technique particularly beneficial for applications like virtual reality," Tölli explains.

Future Talent Pool

Tölli calls for developing expertise in communication and signal processing. He underscores a future where such skills will be as critical as the technology itself. "To transition to 6G, we need to build robust networks, but we also need to nurture the minds that will sustain and evolve them," he concludes.

Related watching:
youtube.com/watch?v=4SBS7GqxS2g

THE CHANGING WORLD OF MOBILE COMMUNICATIONS

5G, 6G AND THE FUTURE OF DIGITAL SERVICES

Produced within the 6G Flagship, the peer-reviewed open-access book The Changing World of Mobile Communications: 5G, 6G and the Future of Digital Services has just been released by Palgrave MacMillan. The book provides the reader with a state-of-the-art, multidisciplinary, and insightful overview and vision of how 6G will develop in terms of business, regulation, and technology management – and how 6G will impact society at large.

The book

- provides a holistic and insightful view of the future of mobile connectivity as the backbone for all digitalisation.
- combines the technical and business-related perspectives of the field in exploring the unique and vast business potential while addressing the impact on policymaking.
- contributes valuable insights and new knowledge to all who study, develop, manage, provide, use, and regulate mobile connectivity and related businesses.
- inspires the reader through practical and reality-based examples and industry views on future 5G/6G.

The book seeks to bridge business, engineering, and policymaking domains with a view to informing us about the future. Underpinning the book is the core question of how 5G and 6G can contribute to sustainable value creation and value capture from a business, engineering, and policymaking perspective. The book is targeted at and written for managers, practitioners, policymakers, and students who want to understand what 5G and 6G will be about and how to benefit from them in the future. The authors of the book see 6G as a general-purpose technology platform that will transform societies while also requiring a new approach to innovation.

The Changing World of Mobile Communications is a product of international collaboration and is co-authored by Petri Ahokangas, Marja Matinmikko-Blue, Seppo Yrjölä, Irina Atkova, Marika Iivari, Oxana Gisca, Pia Hurmelinna-Laukkanen and Ahmad Arslan from the University of Oulu, Jillian Gordon from Glasgow University, Paul Timmers from Oxford University, and Georg Serentschy from Serentschy Advisory. The book is edited by Petri Ahokangas and Annabeth Aagaard.

The book comprises three parts. In the first part, the book covers a brief evolution of mobile communications from 1G to 4G before mapping anticipated 5G and 6G developments, presents 16 future scenarios on mobile communications at the user, business, ecosystem, and geopolitical levels of analysis, and looks at sustainability transitions related to 6G.

The second part of the book focuses on 5G and 6G-based services and ecosystems and delves into envisioned business models in 6G. The authors envision future business models for mobile network operators, over-the-top internet giants, emerging new platform companies, and especially for a variety of new entrants expected to deploy local and private networks. The part concludes with a discussion of how to benefit from 6G innovation in general.

Part three of the book discusses the regulatory context and wider national considerations around mobile communications. It presents a regulatory analysis of local 6G services and proposes a new anticipatory regulation approach to regulate future 6G. This part ends with an analysis of how strategic autonomy and national sovereignty-related issues of 5G and 6G should be dealt with. The fourth part of the book takes a look beyond 6G and puts forth opportunities and implications related to future mobile communications for researchers, managers, and policymakers.

The book is freely available online via SpringerLink, and the printed book can be acquired from all major online bookstores.

Read the book via Springer Link

NETWORK EVOLUTION:
INDUSTRY PERSPECTIVES
WITH NOKIA'S PEKKA LUNDMARK

6G Waves invited Nokia's President and CEO, Pekka Lundmark, to shed light on various 6G-related issues. A frank discussion unfolded, from the realities of 5G adoption, to the importance of networks for the AI and cloud revolutions. Lundmark shared his insights on where the mobile technology industry is at today.

What the Numbers Don't Tell Us
While some see consumer enthusiasm for 5G as lacking, Lundmark pointed out that 5G rollout is still in its early stages. He remarked, "5G mid-band is considered the best spectrum for 5G because it can carry huge amounts of data over long distances. And, outside of China, only around 25% of the world's potential mid-band 5G base stations have been deployed so far meaning we haven't seen the full potential of 5G services and use cases yet. Even then 5G is rolling out faster than any previous mobile technology. The GSMA (mobile network operators association) predicts there will be 2 billion 5G mobile connections by 2024, which will result in smartphone traffic more than tripling by 2028."

5G Fixed Wireless Access (FWA) has been described by many in the industry as the "first 5G killer app" because it utilises mobile networks to bring broadband internet to rural and remote communities where fiber isn't available. Lundmark says: "It's a win-win. Operators can leverage the spare capacity and versatility of 5G to bring broadband to underserved homes and small businesses, which helps operators monetize their 5G investments. At the same time, Fixed Wireless Access is helping to increase digital inclusion."

5G is also accelerating the digital transformation of the industrial sector. Nokia's CEO observes: "We're seeing rapid growth of industrial-grade private 5G networks to support AI and cloud-powered automation solutions. These are industries like logistics, manufacturing and mining where you need low latency and the highest possible reliability and security, both for productivity and safety reasons.

He gave examples of what Nokia has been doing recently with 5G applications: "We deployed a private 5G network at Southampton, one of the UK's largest ports, to enhance cargo efficiency via IoT and Machine Learning. We also set up a 5G standalone network at the Agnico Eagle mine in Kittilä, which has digitalised and automated operations, leading to increased productivity."

"The number of Industrial Metaverse applications and Augmented Reality (AR) and Virtual Reality (VR) enterprise solutions are increasing. And as 5G-Advanced starts to be deployed from the middle of this decade, we believe this industrial digitalization will accelerate further with many more use cases emerging. They will be driven by enhanced network capabilities with improvements in uplink, ultra-reliable low latency, high accuracy positioning, and reduced capability for energy-efficient IoT," explains Lundmark. Adding that these innovations will help drive growth in low-cost massive IoT, non-terrestrial networks (NTN) and drones.

The Future is Mobile and Fixed

While our conversation focuses on the mobile networks part of Nokia's business, Lundmark stresses the continued importance of fixed networks in a 5G and even 6G world.

"Fiber is the backbone of connectivity. We need 5G and fiber working together to deliver seamless gigabit broadband to homes and businesses. To meet the increasing demand for connectivity as AI, cloud and XR takes off, we're focused on continued network evolution in both mobile and fixed," says Lundmark.

He points to Nokia and Vodafone's successful trial of passive optical network (PON) technology, which achieved record speeds of up to 100 Gb/s on a single PON wavelength. This is five times faster than the most advanced fiber networks in operation today.

"While 100 gig broadband won't be commercially seen for a while, Google Fiber is already deploying Nokia's 25G PON solution to enhance its existing fiber network and deliver a new 20 gig broadband service to its customers," adds Lundmark as an example of Nokia's future focus.

The Skills Solution: Developing the Right Skills for a Digital Future

We shift gears to a subject currently making headlines: the challenges companies face in ensuring their employees have the necessary skills in a changing world. "Talent development is integral to our strategy," Lundmark affirms.

The key for Finland is not just to attract top talent but also to retain it, especially those foreign nationals graduating from Finnish universities.

"Developing future-fit talent is one of the pillars of our corporate strategy. Our aim is to create a continuous learning culture that supports employees in their pursuit of new knowledge, developing skills and in enhancing their performance. It helps ensure our people continue growing, which helps support Nokia's growth," he adds.

Like many other Finnish firms, Nokia is operating in an international marketplace for the best tech talent, particularly in fields like chip and software design.

"Getting suitable talent requires both local and European-wide attention," says Lundmark. "The key for Finland is not just to attract top talent but also to retain it, especially those foreign nationals graduating from Finnish universities," says Lundmark.

To close the skills gap within Europe, Lundmark underscores the importance of reskilling across the European Union. "We support the European Round Table's Reskilling 4 Employment initiative, which aims to retrain 5 million people by 2030," he confirms.

The Semiconductor Paradigm

Another hot topic in recent years has been semiconductors. Lundmark observes that the pandemic highlighted the critical role performed by networks, while the pandemic-related supply chain disruption underscored the importance of semiconductors to the global economy, as well as the geo-

political implications around the sector. Nokia's CEO doesn't see that trend changing any time soon as, "inevitably the demand for semiconductors will rise with widespread digitalisation. And semiconductors will acquire new capabilities with the integration of AI," he adds.

"While investment in new fabrication facilities is crucial, it is not the sole area requiring attention," Lundmark points out. He endorses initiatives like Europe's Chips Act, which aim to fortify the resilience of the EU's semiconductor ecosystem and ensure supply security. "Europe needs to enhance its chip capabilities," he adds, emphasising the importance of leveraging European strengths in communications chip design.

6G Development: A Finnish and European Vantage Point

From a historical standpoint, Finland and Europe have been instrumental in shaping cellular technologies. While Europe has been actively involved in 5G research, development and standardisation, it hasn't been a 5G frontrunner when it comes to deployment. "That could change with 5G-Advanced and 6G if Europe has the ambition and if it creates a regulatory landscape that fosters investment in R&D and standardisation," says Lundmark.

Nokia has nurtured strong partnerships with academic bodies in Finland, including the University of Oulu. "6G Flagship has been a pioneering force on the international stage," Lundmark affirms. "'Nokia is proud to have supported Business Finland's Veturi initiative to enhance Finland's technology standing on the global stage," he says.

On a European scale, Nokia's leadership in the substantial Hexa-X project has paved the way for its current role spearheading Hexa-X-II. Lundmark stresses, "Our commitment is to a single, globally recognised 6G standard. As well as our work in Europe, Nokia is playing a leading role in the Next G Alliance in North America, and we recently opened a 6G Research Lab in India."

AI's Growing Influence

"AI technology can make networks more agile, autonomous, and adaptive; help identify and address network issues before they affect subscribers; optimise network resources for network performance and efficiency; reduce energy consumption without affecting service quality; and assist in securing the network," Lundmark explains.

As a B2B technology innovation leader, Nokia is at the vanguard of industrial AI applications. For instance, creating col-

laborative environments where factory workers can seamlessly interact with autonomous robots.

"The real-world applications of AI are already showing substantial gains in productivity, efficiency, and safety across various sectors," Lundmark notes while pointing to Nokia's "responsible AI" approach to research and development.

"We adhere to six principles: fairness, security, privacy, transparency, sustainability, and accountability to guide AI's ethical and effective implementation," he continues.

Navigating Telecom's Next Decade: Nokia's Perspective

The telecoms industry is in a transformative phase replete with both challenges and opportunities. Nokia sees itself as a pivotal player in this transformation, delivering the next evolution in critical networking through developing "networks that sense, think and act", which Lundmark believes will be essential for the AI and cloud revolutions.

Nokia intends to continue evolving its products and solutions for network operators to help them meet the growing demand for connectivity in a digital world. Nokia's technology currently enables over 4 billion 4G/5G subscriptions and over 500 million fixed broadband lines globally.

Lundmark notes the challenges the sector faces. Timely network infrastructure investments are required to keep pace with network traffic growth, but in order for that to happen operators need to feel confident they can ensure a return on their investments.

"One of our top priorities is to help operators monetise their services so they can increase their revenue. We believe there are significant opportunities for our CSP (Communication Service Provider) customers for instance with 5G Fixed Wireless Access and with programmable networks. By creating a digital ecosystem of CSPs, webscalers, enterprises, and developers, we can help turn new ideas into new revenue streams. A good example is Application Programming Interfaces (APIs), which delivers network-as-a-code to developers," says Lundmark.

As for expanding its industry reach, Nokia isn't just limiting itself to the telecommunications sector. The company is already a driving force in digitalizing and automating physical industries such as logistics and manufacturing through a range of Industry 4.0 solutions. "Our share of enterprise, government

We believe this will be a new stage in network software evolution, effectively transforming the network itself into an operating system.

and webscale customers will continue to grow over the coming years as we continue Nokia's evolution," Lundmark states.

Even with its global reach, Nokia is not complacent and continues to prioritise R&D investment so it can further strengthen its technology leadership. The company spent €4.5bn on R&D in 2022 with the multi-Nobel Prize winning Nokia Bell Labs leading its innovation of transformative technologies including 6G and AI.

"Some of the most exciting work we're doing at Nokia Bell Labs is on the development of UNEXT (Unified Networking Experience). This is a Nokia initiative to transform networking systems and software the same way UNIX reshaped computing in the 20th century. We believe this will be a new stage in network software evolution, effectively transforming the network itself into an operating system," says Lundmark.

In common with other industries, telecoms is grappling with global challenges such as sustainability and achieving net-zero carbon emissions.

Ending on a reflective note, Lundmark sums up: "The inescapable truth is that there can be no green without digital. Investment in digitalisation leads to more productivity and decarbonisation and greater access to opportunities in employment, healthcare, education and public services. Ultimately, it is about creating technology that helps the world act together. That's how Nokia is helping enable solutions to global challenges."

FINLAND'S CYBERSECURITY
A RESEARCHER'S INSIGHT

Kimmo Halunen, who holds a joint professorship in Cybersecurity at the University of Oulu and the National Defence University, contributes to the broader discussions surrounding the 6G Flagship programme's cybersecurity direction. In this article, he offers his perspective on Finland's cybersecurity landscape and its anticipated evolution.

Cybersecurity Without Borders

The development and research of technology are inherently collaborative at the international level, and this holds true for cybersecurity-related technologies as well. The international sharing of intelligence on vulnerabilities, attack vectors, and cybercrime activities is crucial for enhancing security measures. Stakeholders in such exchanges encompass private entities, official bodies, NGOs, and even individuals and cybersecurity experts.

Many of cybersecurity's challenges are undeniably global. Our devices, applications, and platforms are the creations of international enterprises and supply networks, suggesting that a vulnerability found in Finland could pose issues elsewhere. Conversely, cyber attacks impacting us may stem from vulnerabilities initially originating from other nations.

For Finland, maintaining a leading position in cybersecurity is vital. It allows the nation to not only advance technologically but also to influence cross-border policies, such as those at the EU level, to enhance national and global cyber resilience.

6G and Cybersecurity

Addressing cyber threats requires a blend of legacy and innovation. Emerging technologies like quantum-safe encryption are essential to address issues beyond the reach of current strategies, ensuring secure communications even against the backdrop of advancing quantum computing. Likewise, past lessons in cybersecurity are applicable to new domains, such as within the forthcoming 6G networks and devices.

"At the University of Oulu, we are at the helm of several projects targeting cybersecurity improvements," says Halunen.

"Our team is engaged in the security of critical systems—a significant research focus for us. We are also conducting security verification for IoT devices and assessing the robustness of AI systems. Forthcoming projects will investigate quantum-safe encryption and the security protocols for its deployment. Furthermore, as part of an emerging consortium, we are striving to enhance international cybersecurity intelligence collaboration."

The impending regulatory and market-driven push towards these technologies will likely prompt a faster transition, bringing a host of challenges and extensive work.

Oulu is recognised as a dynamic hub of cybersecurity expertise, which is integral to both academia and the corporate sector and is a foundational element of 6G research.

Facing the Challenges

A significant hurdle in cybersecurity is the pace of digitalisation, which outstrips the progression of security measures, leaving a trail of vulnerable targets in its wake.

The cybersecurity of innovative technologies, particularly quantum computing and AI, is behind conventional IT security. These fields, in conjunction with 6G security, require significant investment to cope with the modern threat landscape.

"With the standardisation of post-quantum cryptography nearing its final stages, integrating these technologies into our systems presents a considerable challenge," Halunen notes. "They differ markedly from traditional encryption methods. Transitioning to these new systems demands thorough planning and a widespread understanding among organisations and enterprises. While quantum computing doesn't pose an immediate threat to current encryption, the impending regulatory and market-driven push towards these technologies will likely prompt a faster transition, bringing a host of challenges and extensive work."

"Nevertheless," Halunen concludes, "these challenges represent opportunities. Those proficient in managing this shift are set to emerge as leaders in the future digital economy, harnessing both strategic influence and commercial prospects."

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INTEROPERABILITY IS THE NAME OF THE GAME IN

THE FUTURE OF TRAFFIC

An F-35 fighter plane has 8 million lines of code. A modern car, by comparison, has hundreds of millions of lines of code. The car is on its way to becoming an even more demanding software platform than the cell phone, says Tero Päivärinta, professor of Empirical Software Engineering at the University of Oulu.

"The car is an IoT device (Internet of Things) and a very software-intensive one. From a researcher's point of view, there is an enormous amount of things to investigate and problems to solve," Päivärinta says.

As society pushes toward smart traffic that's populated with semi-autonomous vehicles–and eventually fully autonomous ones–the interoperability of different systems is crucial. For traffic to become safer, cars and other vehicles must be able to react to their environment and to other vehicles.

"We create huge demands for mobile communications and connectivity if we want cars to be aware of their context. But we also need software for connectivity, for controls that assist the driver, and eventually for work and entertainment applications. All these interfaces will have to be standardised to ensure interoperability," Päivärinta explains.

As Päivärinta sees it, all this spells good news for software companies. Instead of writing software for one specific car brand, a software company will create products for the lot of them. The software ecosystem will be redefined, and this is going to be crucial for the European automobile industry, says Päivärinta.

"Europeans must be able to compete with American and Chinese manufacturers, and this requires the foresight to work on standardisation and creating clusters instead of rallying behind a single brand or manufacturer. In fact, Oulu is a car city because of the local automotive cluster that consists of roughly a hundred companies. Most modern cars in the world today contain software that has been developed in Oulu."

From the road to the skies

If we look at mobile phones today, we can get a fairly clear idea of what the car will become in the future. Phones are very complicated devices that nevertheless work together: you can use any manufacturer's cell phone in any operator's network to call any other cell phone worldwide. The infrastructure and interoperability we take for granted when making a phone call or posting a selfie will have to be developed for smart cars driving on smart roads in smart cities. The smart traffic of the future is not only wheels on asphalt; it is also vehicles aloft, up in the air.

I want to have 6G be like air or electricity, something that makes things happen but without us having to think about it.

"Urban air mobility changes the game significantly. When you can use elevation, you get quite literally a completely new perspective on any given situation," says **Jussi Haapola**, an Adjunct Professor at the University of Oulu, who is working on vertical application areas of wireless communications. Transporting cargo and people, air rescue, monitoring terrestrial traffic, and creating public safety applications are all examples of intense development in air mobility. Air and ground communications will play a big part in creating future solutions, and it requires ultra-fast and ultra-reliable data transfer, or what 6G promises to deliver.

"The idea for 6G is that a huge amount of information is available from innumerable different sources and is processed intelligently and rapidly. This will enable real-time traffic planning and help create 'see-the-invisible' solutions, where the driver or the vehicle will get a notification of something that's around the corner and requires attention," Haapola says.

"I want to sit in the back seat"

6G is not the end goal but rather an enabler of things, something both Päivärinta and Haapola are keen to emphasise. "I want to have 6G be like air or electricity, something that makes things happen but without us having to think about it," Haapola says. And in time, faster and more reliable data transfer and computing will help us create the smart traffic of the future. But what will that future look like?

"I want to sit in the back seat, first of all," Haapola laughs. "I want to work, have meetings, read newspapers online or whatever I feel like. I also don't want to do those things on the phone. Maybe the phone will be in my backpack, but the car will be my interface to everything."

Tero Päivärinta paints a similar picture.

"Much like cars will have digital representations in traffic; you will have a digital twin the car recognises. Seats will be adjusted, and streaming services will automatically be selected according to your profile. 6G will have a major impact on how you use your time while travelling, whether for work or recreationally."

Driving into the Future

Automotive research is evolving into a multidisciplinary field, encompassing software, sensors, and wireless technologies alongside traditional mechanical engineering. The University of Oulu's Adjunct Professor Kari Liukkunen, and M3S University Lecturer Pertti Seppänen, spearhead the 6G Visible project, which epitomises this transformative approach. The project is done together with the Finnish Meteorological Institute and industry. A central aim to explore how 6G technologies can meet the stringent requirements set by Autonomous driving, ranging from functionality and security to reliability.

"The research topic is the development of autonomous driving using our own wireless 5G/6G networks and distributed computing solutions as a basis for the collection of extensive situational information, data analysis and decision-making. The research and its results can be used especially in companies developing software in the Finnish automotive and transport equipment industry in the development of know-how and new business opportunities," says Pertti Seppänen.

The project offers a concrete, intelligent traffic use case for developing and testing software solutions and architectures. The following companies are involved in the project: DIMECC, Remoted, Siili Auto, SpectacularAI, Sitowise and Elektrobit.

Read more
oulu.fi/en/news/university-oulus-project-combines-6g-technology-and-autonomous-cars

6G Flagship Team Assesses Starlink's Efficacy in Rural Finland

A study by the University of Oulu's 6G Flagship evaluated Starlink's satellite service in Finland's rural areas. Conducted from Oulu to Suomussalmi, the aim was to assess Starlink's potential in ensuring consistent internet access in typical Finnish cottages.

Researchers conducted tests across various sites, noting successful downlink rates above 100 Mbps in most locations, with a decrease to around 65 Mbps in wooded areas. Uplink speeds were between 15 and 40 Mbps, and connection times were under 15 minutes.

The study noted limitations near the Russian border due to Starlink's service policies. Despite this, Starlink showed promise as a reliable service, though environmental elements may influence speeds, and Finland's Starlink satellite coverage is less dense.

These insights are helpful for stakeholders aiming to improve Finland's digital connectivity in remote regions. The results can also be used in other countries in the development of telecommunications in remote areas.

Read more
6gflagship.com/news/6g-flagship-team-evaluates-starlinks-performance-in-rural-finland

CENTRIC
AND THE EVOLUTION OF 6G

In 2023, the telecommunications landscape welcomed CENTRIC, a project to advance wireless communication capabilities. Supported by substantial funding and collaboration of various parties, CENTRIC, under the leadership of Nokia-BL and participation of the University of Oulu (PI Professor Mehdi Bennis), initiated its mission from January 2023 to June 2025 to contribute to the development of 6G.

CENTRIC's Vision for 6G: Beyond Connectivity

The heart of CENTRIC's approach to 6G is not just about faster speeds or broader bandwidths. It's about a paradigm shift in perceiving and designing wireless networks. At its core, CENTRIC envisions an AI-enabled, user-centric, and energy-efficient air interface.

But what does this mean for the average user? Envision a future where wireless networks are more than just passive carriers of data; they're intuitive systems attuned to your needs. With CENTRIC's vision for 6G, this becomes a reality. Picture being on a video call as you navigate a bustling city. As you move from the din of a busy street into the tranquillity of a cafe, the network doesn't just maintain your connection—it proactively enhances your call's audio clarity and video stability.

Innovations: The Technical Pillars of CENTRIC's 6G Ambition

The 6G Radio Access Network (RAN) is at the forefront of CENTRIC's endeavours. It's the foundation upon which the next generation of connectivity will be built. But what sets CENTRIC's approach apart?

The answer lies in their emphasis on the Quality of Experience (QoE). In telecommunications, QoE is a holistic metric

that captures everything from the stability of a connection to the responsiveness of applications. QoE is not just about signal strength. It's about how that signal translates into a seamless user experience.

CENTRIC's focus on QoE is a testament to the project's user-centric approach. By ensuring that the 6G RAN is designed with this metric in mind, they aim to elevate the entire communication experience.

Under the guidance of ALUI, CENTRIC is also poised to share its findings and innovations with the broader telecom industry. The goal? To influence 6G standardisation discussions and potentially pave the way for their innovations to be highlighted in industry white papers and press releases. In doing so, CENTRIC isn't just shaping the future of 6G; it's inviting the entire industry to this revolutionary journey.

> *CENTRIC isn't just shaping the future of 6G; it's inviting the entire industry to this revolutionary journey.*

Bridging Innovations with AI: CENTRIC's Next Leap in 6G

Building on the foundation of user-centric innovations, CENTRIC recognises the transformative potential of Artificial Intelligence (AI) in 6G. Once a buzzword, AI is now a cornerstone of modern technological advancements. CENTRIC's exploration into AI is particularly evident in its development of tailor-made waveforms. These customised communication signals are meticulously crafted, keeping the user's unique requirements at the forefront.

By harnessing the capabilities of Machine Learning (ML), CENTRIC seeks to refine these waveforms, ensuring they align with user needs, hardware limitations, and the propagation environment. The result? A communication landscape where businesses enjoy heightened efficiency, reduced downtimes, and superior user experiences. This translates to swifter, more dependable connections for the everyday user, especially as we navigate the terahertz (THz) and sub-THz spectrum complexities. Moreover, CENTRIC's foray into AI-driven transceivers is set to redefine large-scale deployments, especially in the millimetre-wave (mmWave) spectrum.

The Road Ahead: CENTRIC's Anticipated Impact on 6G Development

As CENTRIC continues its journey, its aspirations extend beyond mere technological advancements. The project envisions a ripple effect that will resonate with academic, industrial, and commercial communities dedicated to the evolution of 6G systems. By aiming to publish their insights in prestigious academic fora and potentially generating valuable intellectual property (IP), CENTRIC hopes to strengthen the European industry's position as we approach the dawn of 6G.

With plans to make datasets and environments developed during the project publicly available, CENTRIC promotes a shared and open approach to 6G advancements. As the project unfolds, its ongoing efforts not only promise transformative impacts on telecommunications but also set the stage for Europe to lead the next era of wireless communication.

AKIHIRO NAKAO

UNIVERSITY OF OULU'S FIRST GUEST PROFESSOR

In a landmark development for September 2023, the University of Oulu welcomed Professor Akihiro Nakao as its first-ever guest professor. A renowned faculty member at the University of Tokyo, Nakao brings a wealth of experience in computer science and next-generation cyber-infrastructure.

The appointment serves a dual purpose: it enhances the University of Oulu's existing research initiatives and strengthens the Finnish-Japanese alliance in 6G research and development. "I'm deeply honoured to join the University of Oulu as its first guest professor. The unique collaboration between industry, academia, and government in Finland has particularly impressed me," Professor Nakao shares.

> ## We should drive from values to technology. That's a significant challenge for 6G.

The Future of 6G: A Collaborative Vision

When discussing the collaboration between Nakao Research Laboratory and the 6G Flagship programme at the University of Oulu, Professor Nakao emphasises the global significance of 6G. "6G is a globally significant topic because we have to define the next-generation mobile network infrastructure," he states.

He identifies areas where 6G Flagship excels—such as fundamental wireless technologies and different wireless test environments—and contrasts them with his own lab's strengths in softwarisation, virtualisation, and network architecture. "We can bring in expertise and build a whole system, exercising our expertise," Nakao adds. This complementary approach, he believes, holds the key to addressing the challenges of transitioning from 5G to 6G, particularly in understanding the societal value this new infrastructure can offer.

Challenges and Values: The Road from 5G to 6G

"Deployment of new generation mobile infrastructure is moving very slowly because you have to deploy lots of base stations and systems, and it's not yet going as planned," Nakao notes.

He then shifts the focus to the societal aspects. "It's crucial to understand the values that 6G can bring to society," he says. This is particularly true in areas like extended communication coverage. "In Japan, for instance, there are several areas—mountainous regions or oceanic expanses—where people can't use a cell phone due to lack of signal."

"Telecommunication serves as a lifeline for these communities," Nakao adds. He also underscores the importance of aligning technological development with societal values. "We should drive from values to technology. That's a significant challenge for 6G," he asserts.

Nakao's perspective dovetails with the University of Oulu's approach to 6G research, which also emphasises the societal impacts of technological advancements.

Democratising Telecommunications: A Japanese Model

Professor Nakao's work in Japan's local 5G initiatives presents a compelling case for democratising access to mobile network technology. "In Japan, we have a unique regulation known as 'local 5G.' Unlike traditional models where only telecommunications companies are granted licenses for mobile networks, this regulation allows regular individuals and businesses to obtain their own 5G licenses," Nakao details.

"The Japanese government recognised that 5G deployment was proceeding slowly and decided to open the field. This accelerates the adoption of 5G and fosters innovation by allowing people to tailor networks to their specific needs. Such local customisation may lead to defining requirements to 6G. Also, Local5G is especially meaningful in that it allows multiple stakeholders to cultivate viable use cases".

"This regulation allows individuals and businesses to deploy their own 5G networks on properties they own. It's like a Wi-Fi network, but it's licensed, it's secure, it's robust," Nakao clarifies. He suggests this as a model that other countries could potentially adopt. However, he also warns that it's not without its challenges, such as the need to solve signal interference problems.

A Partnership for Tangible Solutions

In his candid, face-to-face interview with 6G Flagship, Professor Akihiro Nakao offered a nuanced understanding of the future of 6G, the challenges of transitioning from 5G, and the potential for democratising telecommunications infrastructure.

As we wrap up our conversation, it is evident that Nakao's appointment as the first guest professor at the University of Oulu is not just an academic exchange but a strategic collaboration that can accelerate real-world applications of 6G technology. By combining Nakao's expertise with the University of Oulu's strengths in wireless technologies, the cooperation is set to produce tangible solutions that can be integrated into our daily lives, from enhanced mobile connectivity to more equitable access to telecommunications.

See also NakaoLab:
nakao-lab.org

TELECOMS IN TRANSITION: NICT PRESIDENT HIDEYUKI TOKUDA DISCUSSES THE EVOLUTION

TOWARDS INDUSTRY-LED R&D

Professor Hideyuki Tokuda, President of Japan's National Institute of Information and Communications Technology (NICT), recently delivered a thought-provoking keynote at a 6G Flagship event. His insights offered a fresh perspective on seldom-discussed yet crucial aspects of future network communications: the necessity for precise timing, a shift towards industry-led research, the growing relevance of defence-related initiatives, and the pivotal roles of IoT and challenges in its interoperability within the unaligned heterogeneous IoT communication protocols. In an era of Finnish-Japanese collaboration, these topics demand closer attention.

The Fine Grain of Network Timing

In the world of telecommunications, discussions often revolve around speed and capacity. However, Tokuda emphasised a less-talked-about but equally vital aspect: precise timing. "A difference of just one nanosecond can lead to substantial deviations," he noted. This emphasis on precision speaks to the meticulousness required for developing next-generation networks and, for example, novel sensing and accurate positioning with radio. Beyond the transistors and bandwidth, there exists a domain that calls for innovation—a focal point where Finnish and Japanese experts pool their intellectual resources.

This focus on timing has implications not only for network efficiency and applicability of multimodal sensing but also for verticals that demand synchronisation, such as autonomous systems and metaverse.

Pivoting to Industry-Driven Research

Shifting gears from the micro-level of network timing, Tokuda also delved into how research and development dynamics are evolving. "There's a shift towards industry-led, de-

mand-driven research," he said, pointing out the broader strokes in the tapestry of technological advancement. While the industry's driving seat may no longer exclusively belong to academia, this shift doesn't spell the end for conventional models but calls for their recalibration. In the future, industry partnerships will play an increasingly pivotal role in shaping the future of telecommunications research and development. However, according to Tokuda, investing in basic research funding is still very important.

The Convergence of Defense and Telecommunications

During his keynote, Tokuda highlighted the growing interplay between defence and telecommunications. The defence sector's involvement is becoming more pronounced in an era where national security relies heavily on secure and resilient communication networks. It is essential to integrate TN (Terrestrial Networks) and NTN (Non-Terrestrial Networks) seamlessly to realise a robust 3D network. Tokuda noted that Japan's unique situation necessitates a keen interest in cybersecurity and cyber defence. This convergence of defence and telecommunications underscores the need for robust and secure communication protocols to safeguard critical infrastructure.

Unlocking the Potential of IoT

In the backdrop of Tokuda's insights lies the critical role of communication protocols. These protocols serve as the backbone of modern communication networks, enabling devices to exchange data efficiently and securely. With the emergence of 6G and beyond, the demand for interconnecting solutions above heterogeneous protocols that can

accommodate the diverse requirements of IoT, defence applications, and high-speed data transmission has become increasingly evident.

Professor Hideyuki Tokuda's keynote address not only challenged but also aligned with prevailing concepts in telecommunications. His insights create an intellectual bridge between the Finnish and Japanese ecosystems and underscore the benefit of international cooperation. As the future of telecommunications takes shape, precision timing, industry collaboration, defence considerations and integration will undoubtedly be at the forefront of research and development efforts.

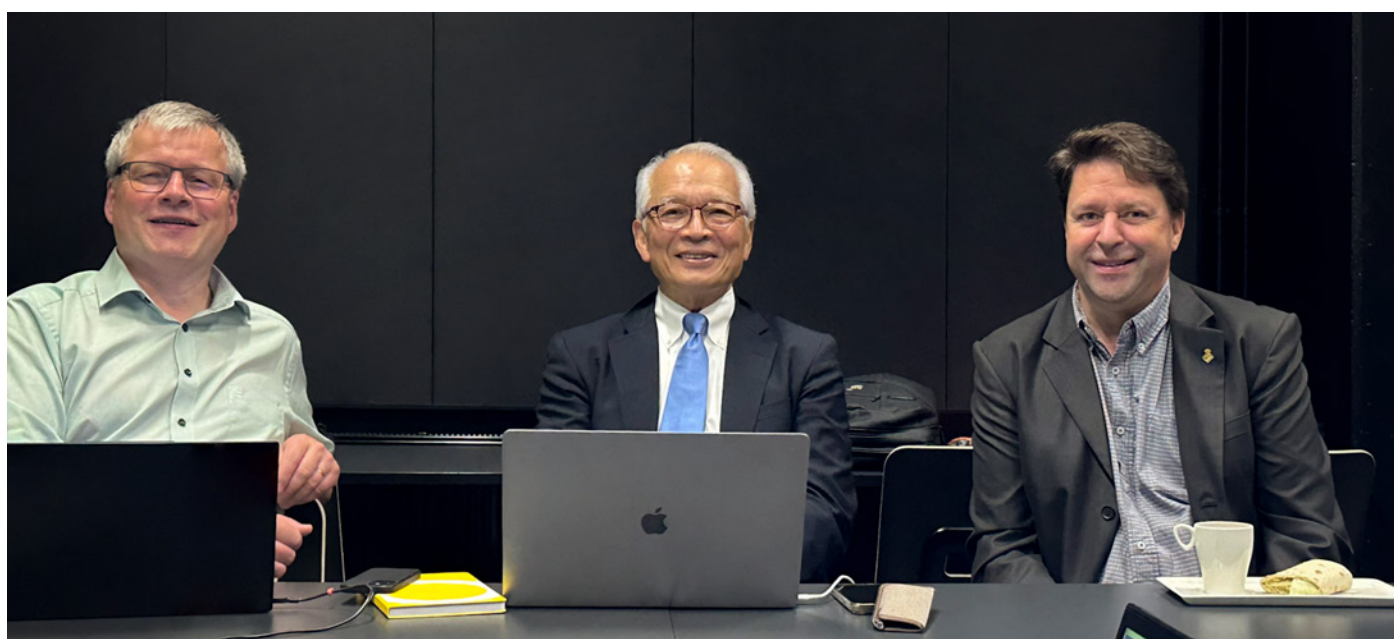## Read more about 6G Flagship Japanese collaboration

6gflagship.com/news/japanese-delegation-and-university-of-oulus-6g-flagship-collaboration-driving-innovation-in-future-wireless-technologies

6gflagship.com/news/finnish-japanese-6g-cooperation-strengthens

6gflagship.com/news/finland-and-japan-agree-on-6g-technology-cooperation

University of Oulu Dean Jukka Riekki, NICT President Hideyuki Tokuda and 6G Flagship Director Matti Latva-aho.

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INNOVATION UNDER THE NORTHERN LIGHTS

WHY CHOOSE FINLAND, OULU AND THE 6G FLAGSHIP?

Happiest Country in the World

Finland has been ranked the world's happiest country for six years in a row. It is a land where world-class research and innovation thrive; where life is safe and easy. The crime rate is low, the social safety net is strong, the air is clean and pollution-free, and the water is safe to drink straight from the tap.

Finland has excellent public services and a strong economy. Children attend school free, and municipal childcare and universal healthcare are available to all residents. 6G Flagship employees receive occupational healthcare. And the University of Oulu has a special Spouse Programme, which helps the whole family to adjust to the Finnish society.

High Tech Up North

The city of Oulu is the home of 6G Flagship. The city is located in northern Finland, which is widely regarded as one of the world's safest and most stable regions. With only 250 000 residents, Oulu is quite compact, but it is also very smart! A whopping one third of the residents has a university degree.

Oulu is a major high-tech hub, with 50 years of experience in ICT and related operations – technologies used by almost 3 billion people every day. The university of Oulu has a long history with telecommunications technology, and particularly wireless telecommunications research. It has been a strength of the university since the 1st G in the 1980s.

> *The big pro of Oulu is an optimal life-work balance, I think it's one of the best - better than Stockholm, better than Helsinki. Why? Life is so easy and simple. You don't have to commute. My gym, my supermarket, my house, my office are within half an hour's walk. I don't have to drive, I just bike to work. To me this is unbeatable.*

— **Professor Mehdi Bennis**
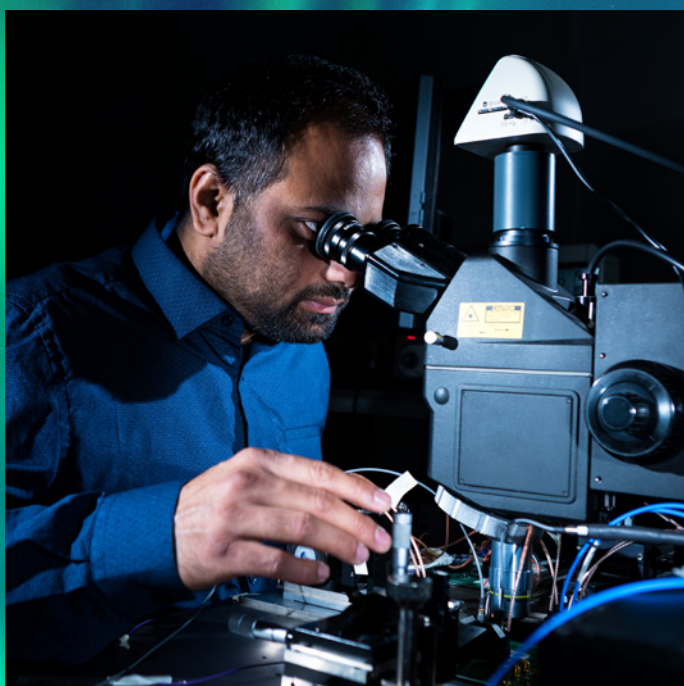
Compact City – World-class Research

The university is home to the world's first 6G research programme, 6G Flagship, where top innovators and leading experts work passionately to build a data-driven, sustainable future society.

Professor **Mehdi Bennis,** one of the world's most highly cited researchers and and a Professor at 6G Flagship, summed Oulu's appeal to world-class researchers perfectly: "The big pro of Oulu is an optimal life-work balance, I think it's one of the best - better than Stockholm, better than Helsinki. Why? Life is so easy and simple. You don't have to commute. My gym, my supermarket, my house, my office are within half an hour's walk. I don't have to drive, I just bike to work. To me this is unbeatable."
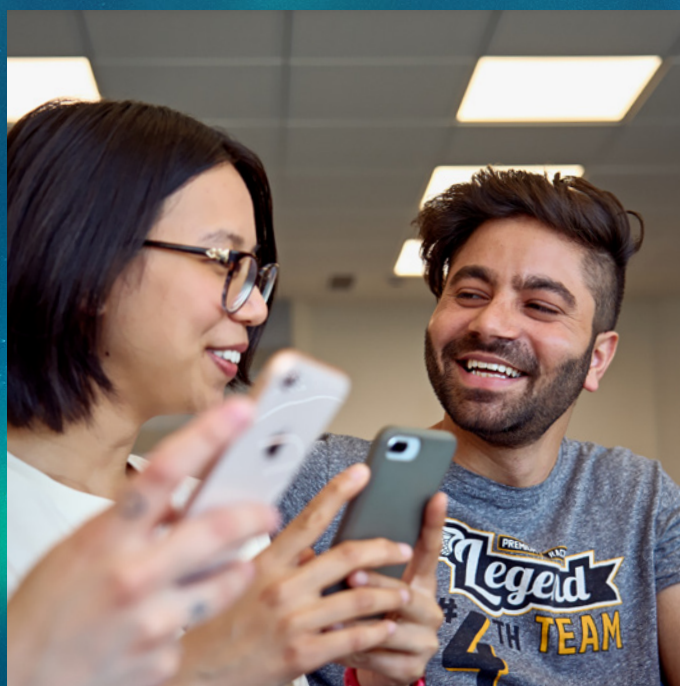
Join the crew of trailblazers in 6G

6G Flagship is continually looking for new talents. We offer positions for doctoral and post-doctoral researchers in four research areas:

- **Wireless Connectivity**
- **Devices and Circuit Technology**
- **Distributed Intelligence**
- **Human-centric Wireless Services**

Are you the trailblazer we are looking for? Apply to one of our four research areas and help us shape the future of wireless communication!

Read more and apply:
6gflagship.com/careers

6G FLAGSHIP IN NUMBERS
MAY 2018 - OCTOBER 2023

Staff

501
experts in 2023

54
Nationalities

63% International

Doctoral Degrees

98
Doctoral degrees

310 746
Doctoral thesis downloads*

Company Collaboration

442
Company collaborators

48% International

Investments & Funding

445
Research projects (external funding)

121
Companies investing in research portfolio

Publications

2 890
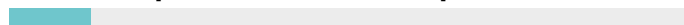**Peer-reviewed publications /
Journal and conference articles**

76% Joint publications with collaborators

67% Joint international publications

12% Joint publications with companies

6G Waves

331 536
Total downloads*

6G White Papers

162 963
2019 White Paper downloads*

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2020 White Papers downloads*

1 078 076
Total White Paper downloads*

* Number of downloads in University of Oulu repository *jultika.oulu.fi*

6G SYMPOSIUM

April 9-11 2024 · Levi Summit, Finland

Welcome to the 6G Symposium 2024

6G Flagship joins 6GWorld in organising the 6GSymposium Spring edition at Levi, Finland—the very place where 6G's journey began in 2018. This time we bring you two days of 6GSymposium, **9th and 10th of April** and in addition, a special research-focused 6G Flagship day on **11th April** powered by Business Finland and 6G Finland.

Critical Conversations at a Critical Time

Coming after the impacts of WRC-23 and before 3GPP begins 6G standardisation work with Release 20, 6GSymposium comes at a vital time in the development of telecoms' next generation.

We'll bring together stakeholders across the value chain, from R&D to the end user, telcos to satcos and from policymakers to security experts. Join us – the critical movers and shakers in the industry!

6G Sumposium Spring 2024 in a nutshell

· Two days of conference, focusing on thought leadership and interaction
· Half-day side-event by Business Finland bringing together other potential client or collaborator industries, such as energy, manufacturing, etc.
· Full day addressing research projects & programmes by 6G Flagship & Hexa-X-II
· Space for private meetings and discussions
· Live demos of relevant leading-edge technologies
· Banquet for all guests offering local specialities
· VIP excursion to a secret location

Join us at the Summit

The **Levi Summit conference venue and hotel** lies in the Arctic circle about 15 minutes' drive from Kittilä International airport. The Kittilä airport has direct flights from all across Europe, including the UK, France, Germany, Austria, Switzerland and Belgium, as well as regular flight connections from Helsinki.

Read more:

6gworld.com/6gsymposium-spring-2024

NORDIC CONFERENCE ON
Digital Health and Wireless Solutions

Welcome to the Nordic Conference on Digital Health and Wireless Solutions

Hosted May 7-8, 2024 in Oulu, Finland—a leading hub for technological innovation—the Nordic Conference on Digital Health and Wireless Solutions is a pivotal event for professionals, researchers, and industry leaders. This conference is organised by the **6GESS** and **DigiHealth** research programmes from the University of Oulu.

Oulu stands at the forefront of research and development in digital health and wireless communications, providing an ideal backdrop for this event. The conference offers an invaluable platform to discuss, collaborate, and gain insights into the latest advancements in digital health and wireless solutions.

Read more:

nordic-digihealth.com

The main topics include:

· Digital Health Innovations
· 6G and Beyond for Health Applications
· Remote Healthcare and Telemedicine
· Wireless Technologies and Medical Devices
· Novel Sensors and Bioinformatics
· Utilisation of Citizen`s Own Data
· Digital Health Care Pathways and Virtual Rehabilitation
· Integration of Health Data and Cybersecurity Aspects
· Edge Computing and Future Network Architectures for Health
· Medical AI and Clinical Decision Support,
· Digitalisation in Health Education
· Digital Interventions and Therapies
· User Experience of Health Information Systems
· Health Technology Assessment in Digital Health
· Impact and Business Analysis for Digital Health

Key dates:

15 Nov 2023	Paper submission and registration open
18 Dec 2023	Paper submission deadline
6 Feb 2024	Notification of acceptance
7-8 May 2024	Conference

EUCNC | 6G Summit

Antwerp, Belgium ▪ 3-6 June 2024

Welcome to 2024 EuCNC & 6G Summit

EuCNC & 6G Summit 2024 focuses on various aspects of 5G and 6G communications systems and networks, including cloud and virtualisation solutions, management technologies, hardware components and microelectronic technologies and vertical application areas. The conference is one of the main venues for demonstrating the technology developed in the area, namely within research projects from EU R&I programmes.

We invite researchers from all over the world to present their latest research results within nine tracks:

- PHY - Physical Layer and Fundamentals
- WOS – Wireless, Optical and Satellite Networks
- RAS – Radio Access and Softwarisation
- AIU – Applications, IoT, Use cases
- NET – Network Softwarisation
- OPE – Operational & Experimental Insights
- CMA – Components, Microelectronics & Antennas
- 6VS – Next-Generation Visions & Sustainability

All calls and full list of topics:

eucnc.eu

Deadlines:

Full Papers

26 Jan 2024	Full paper submission
1 Apr 2024	Notification of acceptance
12 Apr 2024	Final paper submission

Tutorials

26 Jan 2024	Tutorial proposal submission
8 Mar 2024	Notification of acceptance
26 Apr 2024	Tutorial presentation submission

Posters

8 Mar 2024	Extended Abstract submission
1 Apr 2024	Notification of acceptance
12 Apr 2024	Extended Abstract final version

Workshops

26 Jan 2024	Workshop proposal submission
8 Mar 2024	Notification of acceptance
12 Apr 2024	Workshop final paper submission

Special Sessions

26 Jan 2024	Special Session proposal submission
8 Mar 2022	Notification of acceptance
12 Apr 2024	Special Session paper submission

Exhibition & Demos

29 Mar 2024	Exhibition and Demonstration proposal submission
15 Apr 2024	Notification of acceptance

We look forward to your submissions and proposals!

Contacts:

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Johann Marquez-Barja, imec – University of Antwerp, Belgium, Local Organiser and Technical Program Chair
Ari Pouttu, University of Oulu – 6G Flagship, Finland, Technical Program Vice-Chair

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