GTPRN NEWSLETTER

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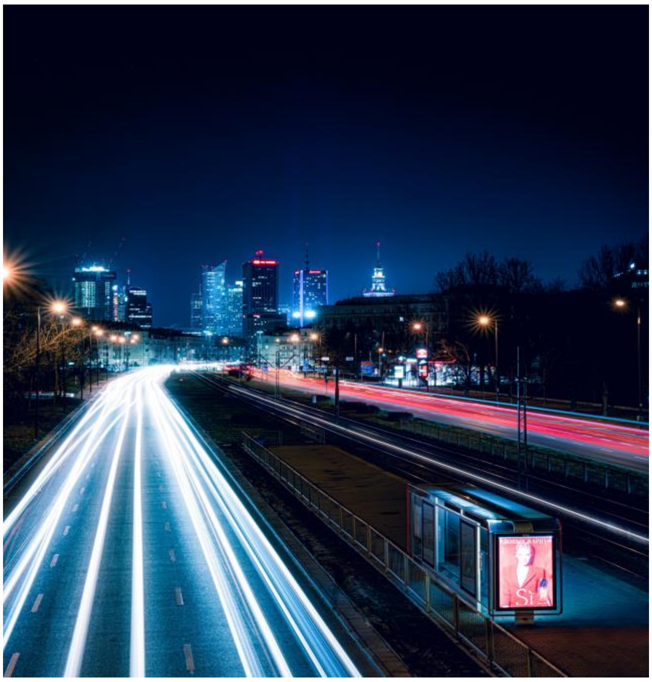


WELCOME TO THE GTPRN 2025 NEWSLETTER

Happy New Year and welcome to the first GTPRN newsletter of 2025! In this issue, we present key insights and discussions on the latest developments in telecom policy, spectrum management, and artificial intelligence. We are very grateful to our distinguished authors and are proud as well to provide our readers with our biggest issue till today with seven exclusive articles from some of the most prestigious names in the industry.

We cannot get enough of our favorite author, **Prof. William Webb,** which has recently published the seminal book, "**The end of Telecoms History**", a must read of any telecom policy researcher. A critical review of the book can be found at the Journal of Telecommunications and the Digital Economy. Check Prof. Webb Article in this issue "**Time for Some Radical Thinking at UHF?"**

The billionaires space race between Amazon's Kuiper and SpaceX's Starlink has highlighted the concept of NTN and D2D in the telecom debate. In this issue, **Prof. Rob Frieden**, Academy and Emeritus Professor of Telecommunications and Law at Penn State University, and the honorable Chairman of GTPRN Board, highlights in his latest article "**Creating Effective Incentives to Conserve and Safeguard Space Resources Before It's Too Late**" several important aspects related to the space race including uncertainties elements in the Five U.N. Space Treaties and challenges related to ITU Consensus Building on Spectrum.

It is worth mentioning that Rob Frieden has recently been awarded the prize of "*Distinguished Researcher*" at PTC-25, the annual conference that focused this year on fiber networks, satellite communications, and subsea infrastructure. PTC has a very active research community under the leadership of **Prof. Heather Hudson**, **Prof. Elizabeth Fife**, and **Prof. Jeniffer Sunrise**, and their PTC young scholar program is an important milestone for any emerging telecom policy researcher. More information on PTC-25 can be found here.

A more technical overview on D2D challenges is provided by **John Pahl,** CEO of Transfinite, and the author of the famous book "**Interference Analysis: Modelling Radio Systems for Spectrum Management**" which is considered as the handbook for researcher interested in conducting technical studies especially within the ITU realm.

Artificial Intelligence is at the heart of several debates within the academia and the industry, and in this issue, we have the privilege of featuring the founder of the ***AI Universal Council,*** **Mr. George Victor**, an initiative focusing on responsible AI with his inspiring article **"The AI Energy Paradox: Advancing Sustainability vs. Climate Footprint".** The AI Universal Council was also founded by **Mr. Naser AlRashdi,** a well-known leader in the MENA region with great influence in the field of space regulation and spectrum management. We cannot get enough of AI and we welcome again the contribution of **Dr. Ahmed Shalaby** on **Macroeconomics of AI**. One must admit that it is rare to find a heart surgeon who is also an expert in digital transformation!

GTPRN is lucky also to feature in this issue two of the biggest names in telecom consulting, **Plum** and **Coleago**, which have been instrumental in framing many elements of telecom management in enormous countries with a focus on niche topics such as spectrum management. **Stefan Zehle**, *CEO of Coleago Consulting*, argues in his article "**Policy and Regulatory Actions Required to Deliver True 5G"** that the current 5G deployments fail to meet the true promise of high-speed, ultra-reliable connectivity. **Selçuk Kırtay** *and* **Tim Miller** *of Plum* examine in their article "**Defense Radio Spectrum Use – Overview of Key Issues"** the complexities of spectrum allocation for military applications, balancing national security needs with growing commercial demands.

We are very thrilled to announce the launch of **GTPRN YouTube channel** with four main webinars that have been successfully conducted recently. You can check more details on the webinars later in this issue and you may watch their recordings at our YouTube Channel.

Finally, you are more than welcome to join our Facebook or LinkedIn Groups, follow us on twitter @GlobalGtprn, or to subscribe directly to our website www.gtprn.org where you have the chance to comment on each article or post.

Take care and stay safe.

GTPRN Team - news@gtprn.org

A YEAR IN REVIEW

It is difficult to conduct a full review on the main publications and conferences of 2024 but one must mention TPRC 2024 with the remarkable keynote speech by **Prof. Johannes Bauer**, Chief Economist, FCC, Quello Chair in Media and Information Policy at Michigan State University, and Director of the University's Quello Center. Prof. Bauer is one of the idols in telecom policy research around the globe and we are certainly glad that telecom regulators appreciate in practice the added value of Prof. Bauer's expertise.

Prof. Bauer is one of the main instructors in the ICT in Developing Countries courses which are provided by the Carnegie Mellon University's Center for Executive Education in Technology Policy (CEE-TP) under the leadership of **Prof. Jon Peha,** Center Founder and Director. The center provides courses that inform government officials and current and future leaders around the world about technology-related public policy issues.

One of the main highlights of TPRC-52 has been the seminal contribution of **Prof. Peter Cramton** and other senior scholars including the Editor in Chief of Telecommunications Policy, **Prof. Erik Bohlin** "***An open-access market for global communications***". The paper provides an overview on the open-access market model which manages network congestion and optimize network use and value and presents an application of the model for intersatellite wholesale communications with optical (laser-beamed) mesh networks in space, showing several efficiency gains. The paper has been recently published in Telecommunications Policy 48 (2024). Prof. Cramton has recently also proposed in **PolicyTracker Podcast** to adopt auctions to allow MVNOs to buy wholesale capacity as has been adopted in the US electricity market.

One of the main events of 2024 has been the mega-conference on space technologies and regulations "**Connecting the World from the Skies**" global forum.

The conference explored topics such as cutting-edge spectrum management frameworks for NTN, pioneering innovations driving the advancement of converged connectivity, the future of lunar communications, and vital importance of space sustainability. The forum also celebrated the winners of the global IEEE competition, focused on innovative solutions for NTN in 6G networks.

Another major publication of 2024 has the been **the Special Issue of IEEE Communications Magazine** on "*Techno-Economic Analysis of Telecommunications Systems*" which has been co-edited by well-known experts in the field including **Prof. Edward Oughton** at George Mason University,

GTPRN would like to take the opportunity to congratulate the leadership of the ITS, **Prof. Jason Whalley** on being appointed in the Board of Directors of TPRC! Another milestone for ITS leadership has been the breakthrough of **Dr. Volker Stocker** and the Research Group "Digital Economy, Internet Ecosystem, and Internet Policy" at Weizenbaum-Institut in Berlin in reaching a record of 94 talks in their well-recognized podcast channels "**Plamadiso - Platforms, Markets, and the Digital Society".** Our favorite pick for 2024 has been "The Universality and Predictability of Technology Diffusion" by **Prof. Doyne Farmer** at the University of Oxford. You can register for Plamadiso's future talks at https://plamadiso.weizenbaum-institut.de/events/

ITS has successfully conducted two main webinars in 2025 namely "*Broadband and Climate Action: Why Digital Policy is Climate Policy*" **Professor Dr. Monika Köppl-Turyna (EcoAustria), Dr. Wolfgang Briglauer (EcoAustria)** and **Joe Rowsell (TELUS)** and also "*Satellite Technology and the Future of Space Regulation*" by **Prof. Rob Friden**. The recordings of the two webinars are available at https://www.itsworld.org.

While not an academic journal, **Strand Consult's** Guest Blog "Telecom Expert Voices" features many exclusive insights by global experts. Our main pick "***LEO Satellites: Revolutionary Connectivity or a Supporting Act?"*** by **Kim Kyllesbech Larsen**. We suggest our authors to check also his own blog *techneconomyblog.com.* Strand Consult has issued another important article covering the implications of President Trump winning the US election on the telecom and technology policy.

Another main publication has been the Special Section on Unpacking Property: Media, Ownership, and Power in Transformation as recently published by the International Journal of Communication and edited by **Sebastian Sevignani** and **Hendrik Theine**. More information is available here.

Make sure also to listen to Prof. Webb's latest podcast by PolicyTracker, the leading spectrum management consulting and news agency, on his latest book "**The 6G Manifesto**". Another important podcast on 6G is by **Prof. Marja Matinmikko-Blue** about the new report published by the Radio Spectrum Policy Group (RSPG) "6G Strategic Vision". You can listen to these PolicyTracker spectrum podcasts here.

INSIDE THIS ISSUE

The Challenges of Direct-to-Device (D2D) Systems

John Pahl, CEO of Transfinite Systems*,* explores the growing interest in satellite-based direct-to-device (D2D) communication, where satellites provide mobile connectivity directly to users without requiring special handsets. The article examines key challenges, including interference management, regulatory uncertainties, and the technical feasibility of ensuring seamless global coverage.

Time for Some Radical Thinking at UHF?

Prof. William Webb questions the long-term viability of terrestrial TV broadcasting and examines how underutilized UHF spectrum might be repurposed. With mobile data demand plateauing and terrestrial TV audiences declining, he argues that it is time for regulators to rethink spectrum allocation strategies for optimal efficiency.

Creating Effective Incentives to Safeguard Space Resources

Prof. Rob Frieden highlights the growing risk of space debris and the regulatory gaps that could threaten future space exploration and satellite communications. He discusses the importance of international cooperation in managing orbital resources and proposes strategies for mitigating risks associated with space congestion.

Policy and Regulatory Actions Required to Deliver True 5G

Stefan Zehle, CEO of Coleago Consulting, argues that the current 5G deployments fail to meet the true promise of high-speed, ultra-reliable connectivity. He examines policy shortfalls, particularly the lack of 5G standalone (SA) networks and inadequate urban coverage and calls for reforms to facilitate small cell deployment and optimize spectrum use.

The AI Energy Paradox: Advancing Sustainability vs. Climate Footprint

George Salama, founder of AI Universal Council, investigates the dual impact of AI on sustainability. While AI is being leveraged to optimize energy efficiency and reduce waste, its own energy-intensive nature presents environmental challenges. He explores case studies from Saudi Arabia and the UAE, where AI and green energy initiatives are being integrated to balance innovation with sustainability.

The Not-So-Simple Macroeconomics of AI

Dr. Ahmed Shalaby critiques the economic framework of renowned economist Daron Acemoglu, arguing that his analysis of AI-driven automation overlooks crucial factors influencing economic growth, employment, and inequality. The article explores how misaligned macroeconomic policies could hinder AI's full potential in fostering inclusive economic progress.

Defense Radio Spectrum Use – Overview of Key Issues

Selçuk Kırtay and Tim Miller of Plum examine the complexities of spectrum allocation for military applications, balancing national security needs with growing commercial demands. The article highlights key policy debates on spectrum sharing, interference risks, and the future role of 5G and emerging technologies in defense communications.

GTPRN WEBINARS

Non-Terrestrial Networks (NTN): Coordinated Integration or Another Competitive Rivalry

On Monday, 16th December, at 3 p.m. GMT, GTPRN hosted an engaging panel on the evolving landscape of Non-Terrestrial Networks (NTN). The discussion brought together leading experts, including Prof. Rahim Tafazolli (University of Surrey), Kezias Mwale (African Telecommunications Union), Fatima Karim (Global Mobile Suppliers Association), Amr Ashour (Eutelsat OneWeb), and Abdulhadi Aboulmal (MEA-COMM). The panel explored key themes in NTN integration, spectrum allocation, and competitive challenges.

Internet Governance Forum 2024 (IGF-24): Towards More Academic Participation

Held on Monday, 9th December, at 1 p.m. GMT, this panel examined the role of academia in shaping Internet governance policies. Esteemed panelists included Christine Arida (ICANN GAC), Chafic Chaya (RIPE NCC), Markus Kummer (Geneva Internet Platform), Anriette Esterhuysen (APC), and Wolfgang Kleinwaechter (GCSC). The session focused on bridging academic research with policy implementation and the broader implications for global Internet governance.

Artificial Intelligence: Opportunities and Challenges

On Thursday, 9th January, at 3 p.m. GMT, GTPRN explored the impact of AI on telecommunications policy and industry. Featuring H.E. Belal Al-Hafnawi (TRC-Jordan), Prof. J. Scott Marcus (CEPS, RSCAS), Prof. Moinul Zaber (University of Dhaka & Cambridge), Dr. Ramy Ahmed (NTRA, ITU-T SG20), and George Salama (AI Universal Council), the panel debated AI-driven transformation, policy implications, and industry advancements.

World Telecommunication Standardization Assembly (WTSA-24): What is at Stake for the Future of Standardization?

On Monday, 2nd December, at 3 p.m. GMT, GTPRN convened an expert panel to discuss the critical policy and regulatory challenges surrounding telecom standardization. The session featured Bilel Jamoussi (ITU-T), Ahmed Said (NTRA, Egypt), Tania Villa (IFT, Mexico), Heung Youm (Soonchunhyang University, Korea), Ena Dekanic (U.S. Department of State), Ahmed Rashad (Huawei), and Rob Frieden (Penn State University). The debate centered around the role of global standardization efforts in enabling technological innovation and interoperability.

UPCOMING EVENTS

The **IEEE International Symposium on Dynamic Spectrum Access Networks (DySPAN 2025)** is back this year with a quite anticipated program under the chairmanship of Prof. Simon Saunders in **Strand Campus, King's College London** in the period of *12-16 May 2025***.** The conference will feature keynote speakers including **Prof. William Lehr and David Willis, Group Director of Spectrum, Ofcom.** The conference will also accommodate a special event by the **UK Spectrum Policy Forum (SPF)** "Future Spectrum Policy Summit"

The Research Conference on Communications, Information and Internet Policy, TPRC-53, Calls for proposals is available now and the conference will be held in September 19-20, 2025 at Washington College of Law in Washington D.C..

The other not to miss telecom policy conference will be the **33rd European regional conference of the International Telecommunications Society (ITS)** under the theme "**Digital innovation and transformation in uncertain times**". The conference will be held on *30th June and 1st July 2025* in Edinburgh, UK, and is being hosted by Edinburgh Napier University.

ITS will conduct a webinar on 25th of March "Digital Connectivity and Urban Mobility" by **Dr. Betsy Donald and Dr. Shauna Brail** on their recent book ***Urban Mobility: How the iPhone, COVID, and Climate Changed Everything***. You can register here for the event.

IEEE International Conference on Communications (ICC) 2025: Organized by the IEEE Communications Society, ICC is an annual conference focusing on the latest advancements in communications technologies, including wireless, optical, and satellite communications. The conference will be held in Montreal, Canada on June 7–13, 2025

International Telecoms Week (ITW) 2025: ITW is a premier event uniting leaders from across the digital infrastructure spectrum. It serves as a platform for visionaries and innovators to shape the future of global communications, covering areas such as satellite, subsea, and beyond. The conference will be held in Maryland, USA on May 4–7, 2025.

MAIN PUBLICATIONS

Below are the main publications on telecom policy in the last eight months:

- Telecommunications Policy
- Telematics and Informatics
- Journal of Telecommunications and the Digital Economy
- Intermedia, the International Institute of Communications quarterly journal
- Information Economics and Policy
- Digital Business

JOBS OPPORTUNITIES

ADB Internship Program: The ADB Internship offers graduate students the opportunity to work in a major international development organization with a multicultural environment, and gain a deeper understanding of development finance and the impact of ADB

Anglia Ruskin University accepts applications for a fully funded Vice Chancellor's (VC) Ph.D. scholarship on "Emerging Technologies, AI and Power Dynamics in Internet Interconnection: The Impact on Meaningful Connectivity and Digital Inclusion". Deadline to submit applications is March 16, 2025. For queries on the application process, please email phdscholarships@aru.ac.uk.

The Annenberg School of Communication at the University of Southern California seeks applications for a tenure track Assistant or tenured Associate Professor in the area of media industries and economics.

Several consultancy opportunities are available at the **ITU** including Digital Government Consultant

The Challenges of D2D Systems

JOHN PAHL, TRANSFINITE SYSTEMS LTD

THE ISSUE

Abstract: There is currently significant interest in the satellite and mobile industries in the potential to provide communication services from satellites direct to users with unmodified handsets. These types of systems are sometimes called direct-to-device (D2D), non-terrestrial networks (NTN) or supplementary coverage from space (SCS) and could involve a constellation of low Earth orbit satellites with large antennas that can provide such a service. This brings challenges, from the service that can provided, to avoiding causing or suffering harmful interference, as discussed in this paper.

Background:

Early in 2024, SpaceX launched six Starlink satellites with direct-to-device (D2D) capability, highlighting an acceleration of developments in the field of non-terrestrial networks. Previously, in 2023, AST SpaceMobile launched the BlueWalker 3 satellite which successfully connected with unmodified smartphones. Lynk Global is also developing its own D2D constellation. Simultaneously with the development of non-GSO constellations, work within 3GPP on standardization has incorporated support for non-terrestrial networks (NTN) where issues to address include latency and Doppler compensation.

Whereas the engineering and standardization tracks have made progress, the regulatory framework for D2D systems is still under development, with a new agenda item agreed at WRC-23 for WRC-27. Some of the proposed D2D satellite networks are operating under a minimal “no interference, no protection” basis under Article 4.4 and there has been concern that this would not give terrestrial networks sufficient protection or certainty for the satellite network.

This paper considers three of the challenges that D2D systems must overcome:

- How to provide a D2D service?
- How to avoid causing harmful interference?
- How to avoid suffering harmful interference?

How to Provide a D2D Service?

Provision of mobile services direct to a handset from satellite leads to a number of additional issues compared to operating from a traditional base station (BS). The first is the simplest – the satellites are further away from the handset or user equipment (UE). This results in a greater pathloss, as can be seen in the table below, calculated for a frequency of 1,800 MHz:

Case	Terrestrial BS	Satellite
Distance	200 m	500 km
Free space pathloss	83.6	151.5

It can be seen that the free space pathloss is 68 dB greater for the satellite, significantly reducing the signal received. There are also to be restrictions on the power available at the satellite, with the supply constrained by the size of the solar arrays and batteries, unlike the BS connected to a national electricity grid.

The result is likely to be a lower C/N for both uplink and downlink and reduced margin for other propagation losses. In particular, this makes it hard to provide a service indoors or where there is attenuation from vegetation or buildings.

As part of the design process, the D2D system must optimize the coverage and link budgets. Consider a system operating at a height of 500 km which has a minimum elevation angle of 50°, the link budgets could look similar to those in the table below:

Direction	UL	DL
Frequency (MHz)	1900	2100
Bandwidth (MHz)	5	20
Tx power (dBW)	-6	10
Tx peak gain (dBi)	-3.0	31.1
Satellite height (km)	550	550
Elevation angle (deg)	50	50
Distance (km)	698.9	698.9
Free space pathloss (dB)	154.9	155.8
Rx peak gain (dBi)	31.1	-3.0
Receive signal (dBW)	-132.8	-117.7
Receive temperature (K)	300.0	1500.0
Noise (dBW)	-136.8	-123.8
C/N (dB)	4.0	6.1

It can be seen that for typical threshold C/Ns, there will be very little margin available for other attenuations on the link, such as clutter (vegetation, buildings etc.) or indoor-to-outdoor losses. The D2D system can compensate to a degree for this by:

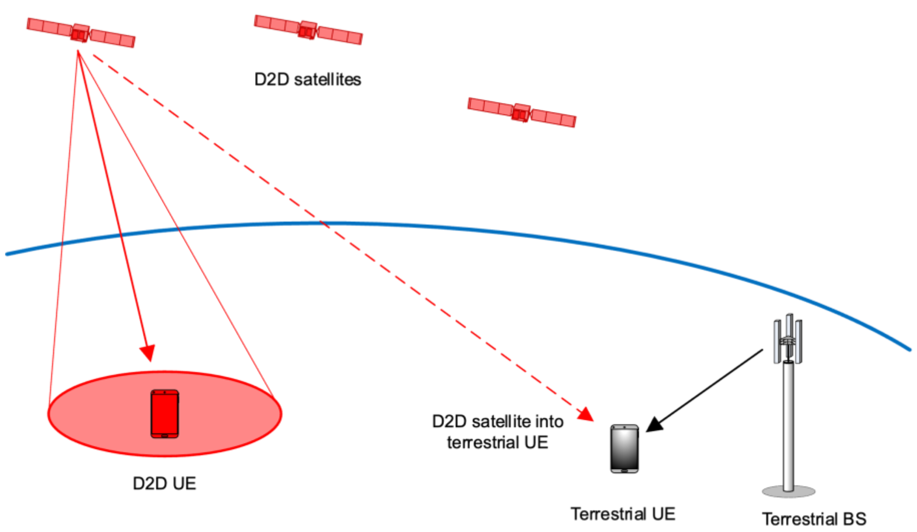
- Lowering the height of the orbit, to reduce the pathloss.
- Increase the satellite antenna gain by using larger antennas.
- Operating only to higher elevation angles, reducing the worst-case path loss and likelihood of clutter.

These factors lead to the need for bigger constellations with larger satellites, but the power that these satellites can transmit could be constrained by power flux density (PFD) limits on the ground. An example would be the SpaceX constellation which is proposing to operate at the lower height of 340 km and use 1,500 satellites. Their application to the FCC also requested that the out-of-band PFD limits be changed to allow higher powers to be transmitted at the satellite.

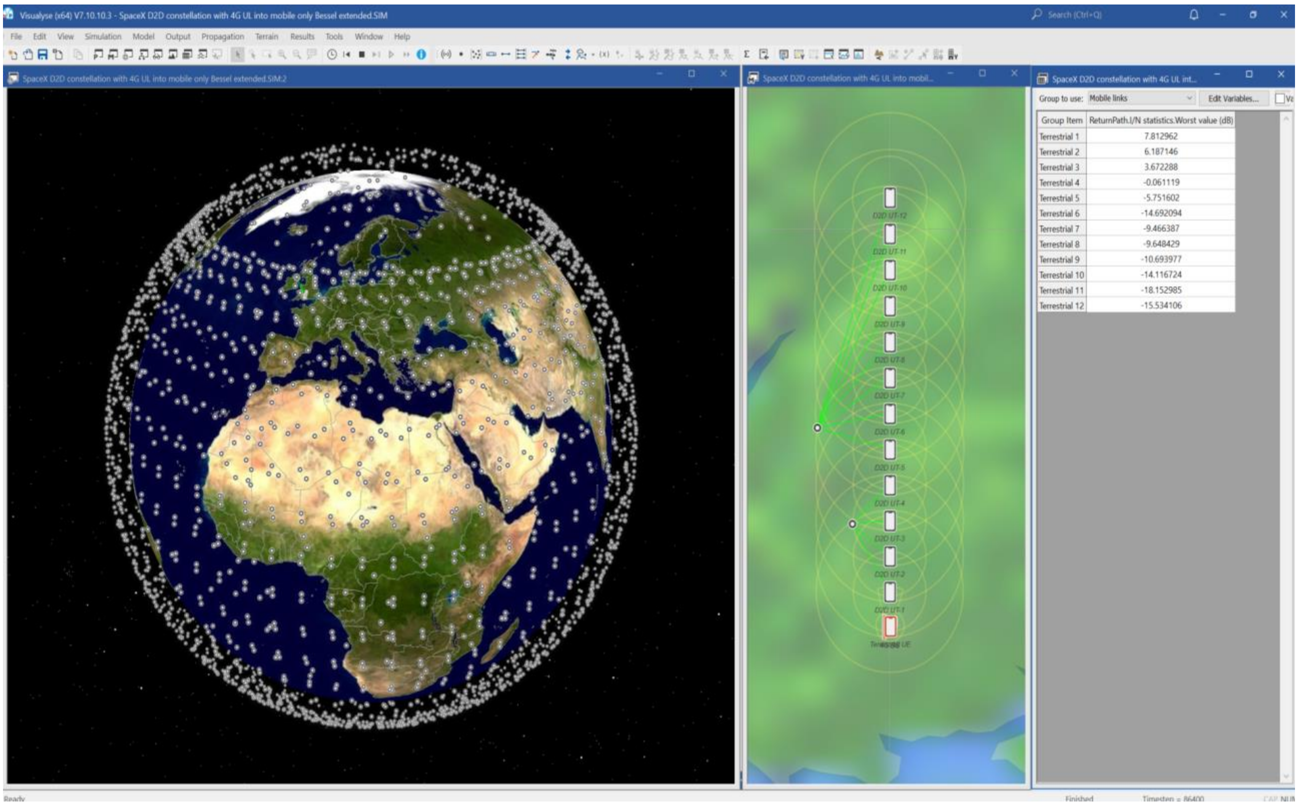
Another factor to consider is Doppler shift: as the satellites move relative to a fixed point on the ground, the frequency of the received signal will vary. This can be compensated for by the satellite automatically changing the frequency it transmits or listens to compensate for this variation.

Avoid Causing Harmful Interference

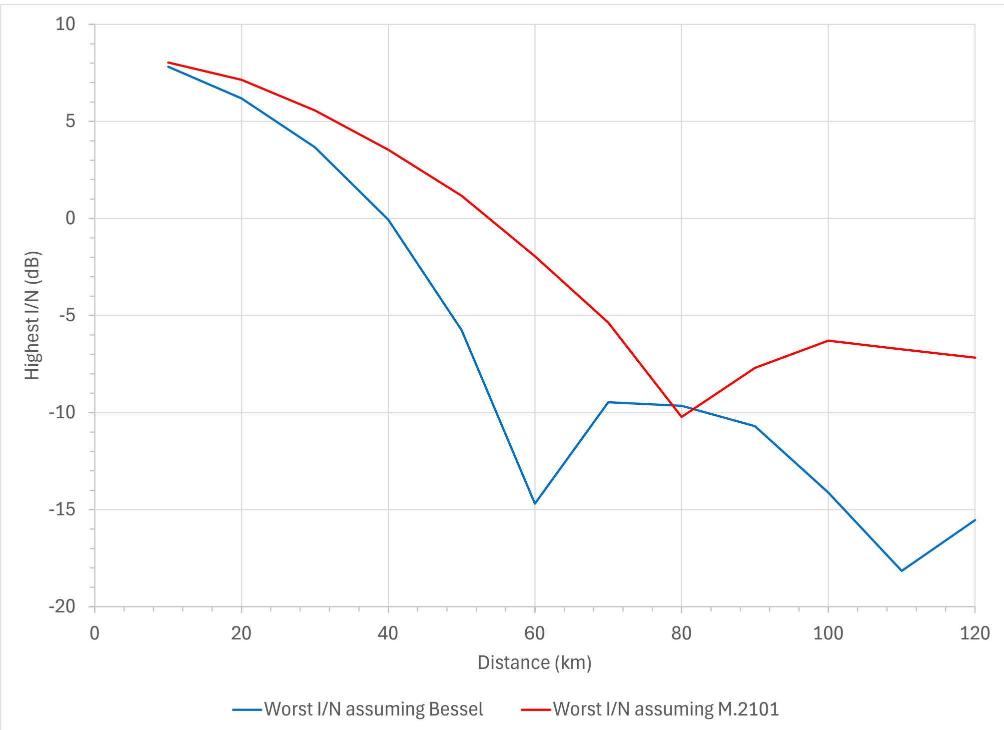
Some D2D systems propose to use spectrum licensed terrestrial mobile systems. This could lead to co-frequency spectrum sharing, as in the next figure:



A key question is how can the D2D system provide a service without causing harmful interference into the terrestrial network? The screen shot below shows an example simulation file that could be used to analyze this problem:



There are a set of D2D links to UEs at a set of equally spaced locations every 10 km from a terrestrial network. The I/N at the terrestrial mobile handset is plotted against distance in the figure below assuming the satellite is using a beamforming antenna with gain pattern modelled using either a Bessel function or Recommendation ITU-R M.2101:



The I/N generally decreases with distance, though if the non-GSO satellite uses a beamforming antenna modelled using a Bessel function or Recommendation ITU-R M.2101, there can be sidelobes that increase the I/N as the distance increases.

In this example, the separation distances required to satisfy an interference protection criterion of I/N = -6 dB can be seen to be around 50 km (assuming Bessel) or 70 km (assuming M.2101), though it could be that a tighter I/N threshold would be required:

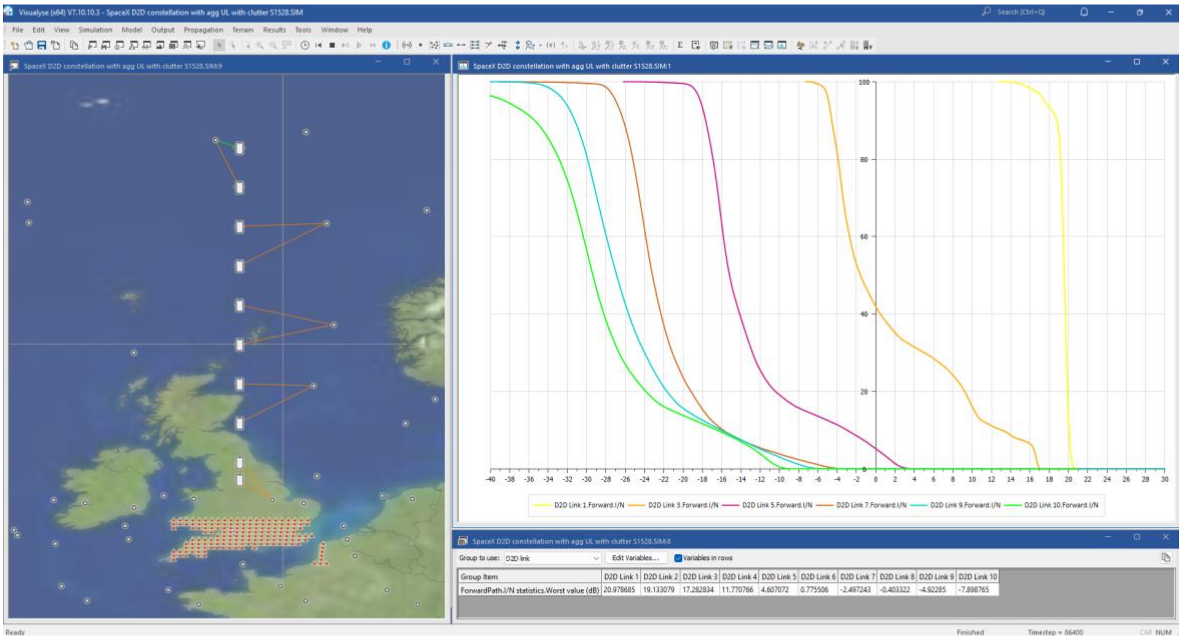
for example, a more detailed analysis would also need to consider the aggregation of interference from multiple beams from multiple satellites, rather than the single-entry interference considered in this analysis.

However, sharing could be feasible based upon a separation distance that depends upon key factors such as:

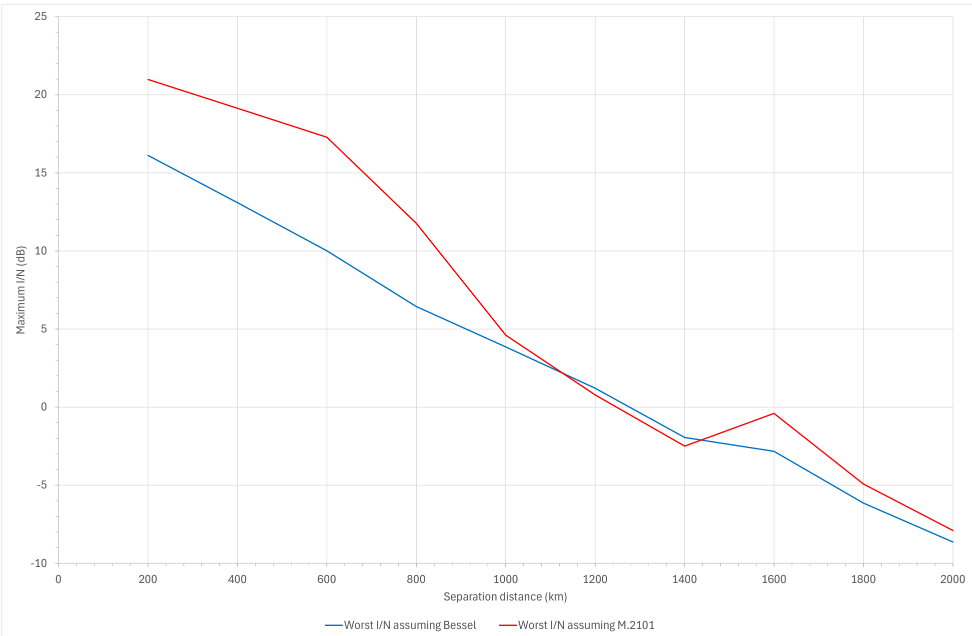
- The aggregation of interference across multiple satellites and beams
- The gain pattern used by the satellite's antenna
- The peak PFD per beam
- The threshold for acceptable interference at the mobile service.

Avoid Suffering Harmful Interference

A D2D uplink could experience interference at the satellite from the large numbers of terrestrial mobile networks within the field of view of the satellite where there could be thousands if not millions of mobile users. It is therefore important to consider the aggregation of interference as in the screenshot below, where each terrestrial object in the simulation represents 1,000 UEs.



For the scenario under consideration, the maximum I/N varies by separation distance and satellite antenna gain pattern as shown in the chart below:



It can be seen that the uplink I/Ns can be high, in particular for those UEs close to the mobile deployment area. This could be analyzed further, for example, considering different gain patterns at the satellite and mobile traffic models and levels. Further analysis could also consider operation in adjacent channels with a combination of frequency and geographic separation.

Conclusions

D2D systems represent a major new market for satellite systems, with a number of high-profile companies investing in new constellations to provide services to unmodified handsets. As noted in this paper, providing a high-quality service that does not cause or suffer harmful interference are serious challenges requiring careful and detailed studies involving software modelling and analyses.

Tools such as Visualize Professional can be used to study these problems and have the potential to optimize system design in a way that can improve spectrum efficiency and facilitate the introduction of new types of service whilst ensuring that the receivers of other services are not exposed to harmful interference.

ABOUT THE AUTHOR

JOHN PAHL

Founder & Managing director of Transfinite Systems

John has over 30 years' experience of the radio communications industry and was one of the founding directors of Transfinite Systems Ltd. Areas of expertise includes:

- Technical analysis, considering topics such as interference analysis, satellite and earth station coordination, terrestrial systems analysis and methodologies
- Regulatory issues, including chairing ITU-R groups that developed Recommendations, active participation in multiple WRCs and CEPT ECC meetings (including acting as CEPT coordinator), and review of the Communications Bill that founded Ofcom
- Spectrum licensing issues, leading Transfinite's team that participated in one of Ofcom's auctions in the UK, leading to the purchase of one of the 28 GHz area licences.
- Training and knowledge transfer in both technical issues.
- Knowledge of a wide range of systems and services, from terrestrial (including 5G, 4G, 3G, BR/PMR, FS/FWA, WiFi, ENG/PMSE, RNSS, broadcasting, radar, white spaces and UWB) to satellite (GSO, non-GSO and HEO) plus others e.g. maritime and aeronautical.
- Detailed understanding of issues relating to the equivalent power flux density metric (EPFD) and its use in verification that non-GSO satellite systems meet the limits in Article 22 of the Radio Regulations using the algorithm in Recommendation ITU-R S.1503 and in Resolution 770 of the Radio Regulations plus associated regulations in Resolutions 76 and 85.

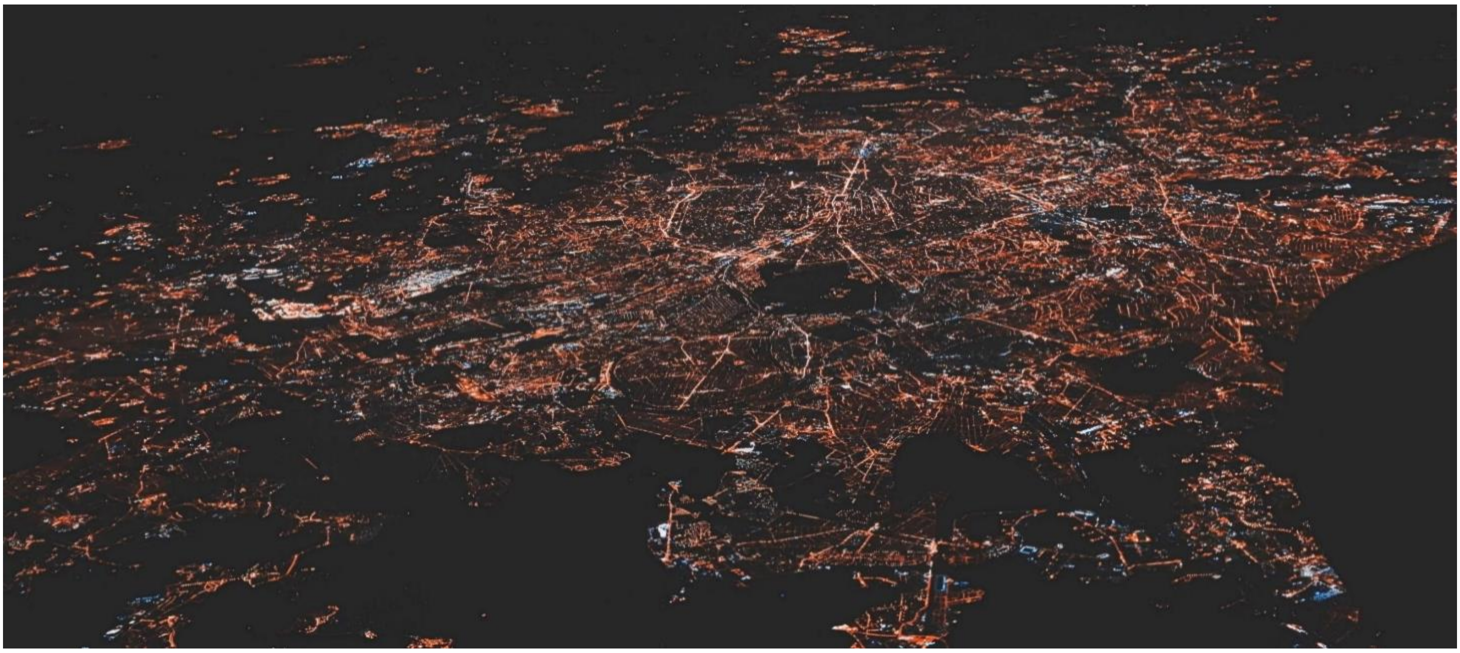
John was the original designer of the company's Visualise Professional radio interference simulation product, and has been heavily involved in its development, support, sales, and marketing including an extension to model systems on or around the Moon and Mars.

John Pahl has a master's degree in mathematics from Cambridge University. He has had papers published in the Journal of the British Interplanetary Society and the International Journal of Satellite Communications, and presented papers at ESA, IEE and ITU-R conferences.

John is the author of the book "Interference Analysis: Modelling Radio Systems for Spectrum Management" published by Wiley in 2016.

Contact: ***Email Transfinite at info@transfinite.com or visit their web site at https://www.transfinite.com***

TRANSFINITE SYSTEMS



TIME FOR SOME RADICAL THINKING AT UHF?

PROFESSOR WILLIAM WEBB, INDEPENDENT CONSULTANT

The history of the UHF broadcast spectrum has been gradual transfers of blocks from TV broadcasting to cellular. This included the 800MHz block used for 4G and the 700MHz block for 5G. In some countries, such as the US, 600MHz has also been transferred to cellular. Simple extrapolation is leading to the question of whether more spectrum should be moved from TV to cellular.

Before going further, it is important to note that there are huge national differences. Some countries barely use terrestrial TV, others still have a large population that rely on it. Some have excellent broadband that can deliver streaming TV, others have less comprehensive connectivity. Hence, the issues will vary by country.

The key drivers of the past transfers of spectrum have been:

1. Ever-growing demand for more cellular data usage, leading to the need for more spectrum to meet demand.
2. Improved TV broadcast technology allowing for more channels to be broadcast with less spectrum.

But these drivers are changing. Firstly, as I showed in my book “The End of Telecoms History” growth in data usage is slowing, and usage is likely to plateau in the next few years. Without much growth in mobile data use there is little need for additional spectrum for cellular networks. Hence, there may be little need the lower UHF frequencies for cellular. Of course, operators will always value more spectrum as it may be useful and it may allow them to reduce costs, but their willingness to pay high prices will be much reduced.

Secondly, improvements in broadcast technology are diminishing – the low hanging fruit has been picked. There is still some scope for a reduction in data rates and hence spectrum usage, but it is less than in the past.

While these drivers have weakened, a new one has emerged. Terrestrial TV networks are becoming increasingly unaffordable. As more viewers move to other platforms – primarily streaming services – then the number of viewers of terrestrial TV decreases but the cost of maintaining the network remains unchanged and hence the cost per viewer rises. Also, many terrestrial TV networks are aging, and there could come a point in the next decade where significant investment is needed in maintaining masts and renewing the active transmission equipment. In some countries, such as the UK, there are dates set for review (2034 in the UK) and possible renewal of the transmission licenses which could act as catalysts for a debate on whether terrestrial transmission is becoming unaffordable. Currently, terrestrial broadcasters vigorously defend their spectrum but a time could come where the terrestrial TV networks may voluntarily turn off and hand back the UHF spectrum.

Against this backdrop of changing drivers, the concept of repacking broadcast TV to a smaller bandwidth so that another tranche of UHF spectrum could be transferred to cellular while still maintaining TV broadcasting makes little sense. It would involve significant cost to re-engineer terrestrial TV networks and may require viewers to update receiving equipment and yet the benefits of the released spectrum will be small, and the remaining viewing base on the upgraded TV network likely to dwindle. Likewise, there is little scope for a cost-reduced platform. Reducing the content transmitted does not materially change the cost of operations, only reducing coverage would do that. But a network with partial national coverage makes little sense.

Instead, the key decisions become:

1. When will we turn off the terrestrial TV network (which may not be for 10 years or more)?
2. After this, what should we use the UHF spectrum for?

The switch-off date will vary by country and will depend on the cost of maintaining the terrestrial TV platform, the penetration of streaming TV and the willingness of politicians to address an issue that could generate bad publicity for them. Around the mid-2030s might be a reasonable estimate for most countries.

What should we do with the spectrum at that point? There could be around 200MHz of UHF spectrum roughly in the band 470-690MHz in most countries (less in those like the US that has already repurposed the 600MHz band).

A first point of note is that PMSE (wireless microphones and similar) is currently a user of the UHF band. Mostly this is on a shared basis, but in any future bandplan some dedicated spectrum could be found for on-going PMSE usage, perhaps 10-20MHz.

Despite the slowing growth, cellular remains a possible user. But these lower frequencies are less attractive to cellular networks. Optimal antennas at 500MHz are around 30cm long – too big for most handsets. Hence, the benefits of improved propagation at lower frequencies may not be realised. These factors suggest that the spectrum will be of relatively low value to the operators, implying other applications might be considered.

Alternative applications might include:

- Wide-area IoT networks such as the Weightless technology developed for TV white space that used the broad bandwidths and excellent propagation to deliver national networks but enable 10-year lifetime for devices. This could be important competition to NB-IoT networks that are sometimes being switched off.
- Satellite direct-to-handset systems. Although these systems might prefer higher frequency bands, using, for example 600MHz might allow current cellphones (designed to work in the US) to be used and provide spectrum that is not being used terrestrially so that ubiquitous coverage can be provided.
- Spectrum for utilities such as power networks. These users require their own networks to deliver coverage and reliability and have been looking at 450MHz, at the bottom of this band. Their application could be expanded up towards 500MHz.
- Railway spectrum to allow railways to upgrade their current GSM-R system towards a 5G solution.
- Unlicensed or lightly licensed spectrum for innovative new applications.

There is more than enough spectrum for each of these applications to gain 10-20MHz alongside PMSE and cellular.

While switch-off may still be a decade away, it is time to start re-casting the debate away from taking the next slice of spectrum from broadcasting, to what to do with the entire band when broadcasting chooses to vacate. Putting in place the studies that can show the benefits of various uses, and then the international spectrum allocations that allow them will mean we can make clear, rational decisions when the time comes. Regional and global discussions will then be needed around how plans to coordinate broadcast networks across regions can be modified and eventually revoked and how ITU allocations can be changed appropriately.

Now that regulators have less work to do freeing up new spectrum for cellular, they can turn their attention to what to do with spectrum that gets freed up without their intervention.

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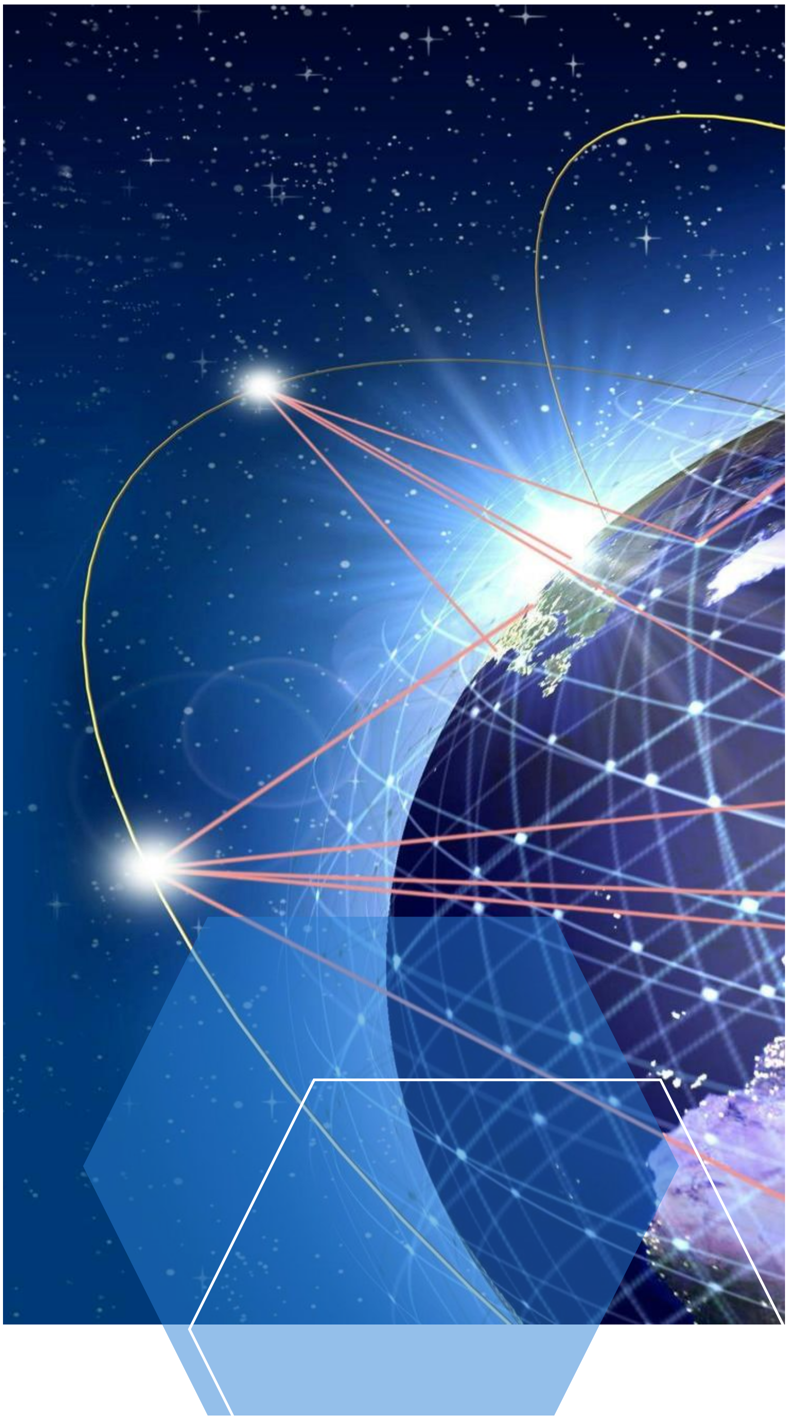
William is a highly experienced strategist, technologist and Board member. His experience spans industry, Government and academia and roles include CTO, CSO, CEO, Board Chairman, consultant and advisor. He has worked for companies from start-ups he co-founded to Motorola and now acts as a trusted advisor, strategist and change-agent for CEOs, senior Government members and others.

His skills lie in bringing about change and innovation in areas where technology and strategy intertwine and where influencing both individuals and wider audiences is important. This has included devising and implementing new strategies for managing the UK's radio spectrum, bring Europe's largest Engineering Institution into the 21st Century, forming a standards body and bringing a range of key industry players onto the Board and advising Secretaries of State and University Vice Chancellors.

Widely renown as one of the most intelligent and capable individuals in the communications arena, he gained the top first class honours degree from the top University in Electronics in the UK. He was one of the youngest Fellows ever elected to the Royal Academy of Engineering, the youngest President of the IET for a century and has been awarded three honorary doctorates and three visiting Professorships and in 2018 the IET's highest medal - the Mountbatten Award.

He has huge commercial experience, starting with an MBA, advising the CEO of Motorola, being part of the Senior Management Team at Ofcom, starting a Cambridge-based high-tech company subsequently sold to Huawei for $25m, and forming and acting as CEO of a standards body. At the IET he was the President where he chaired the Board of Trustees.

He has built a successful portfolio career which a CEO role, member of multiple advisory boards and prestige consulting services including a Board Member of Motability, a Director of the Marconi Society and a member of the advisory board of SpectrumX. He is available for consultancy and longer-term positions.



Creating Effective Incentives to Conserve and Safeguard Space Resources Before It's Too Late

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I. Introduction

Space, "the Final Frontier," has become an attractive, but increasingly risky undertaking by national governments and private ventures. Low earth orbiting satellite networks have the potential to make broadband ubiquitous and affordable, a grand solution to the Digital Divide. Other markets opportunities include:

extraction of precious stones and rare earth minerals from asteroids, including electric vehicle battery components, worth billions of dollars; development of a vibrant space launch and tourism industry; space exploration; colonization of the Moon and Mars; and an expanded array of services via commercial satellites, such as remote sensing, the use of satellites to map, monitor, detect, photograph, and track activities above ground and on earth.

Sadly, several countervailing interests and motivations jeopardize the full development of new commercial markets, as well as ongoing lawful uses of space by public and private actors. A worst-case scenario severely reduces space commerce investment and insurance underwriting, because proliferating space debris increases the risk of costly collisions between abandoned and worthless junk and quite valuable satellites and space stations.

The ambitious plans of Elon Musk, Jeff Bezos, and Richard Branson could crash and burn, despite recent successes, such as SpaceX's plans for 148 rocket launches in 2024, and its projected $6.6 billion in revenues for the year. High ranking current and former U.S. government officials also have issued chilling warnings about the potential for space to become a volatile new theater of warfare, further adding to risk and uncertainty.

II. Reaching an Unrepairable Tipping Point

A chronic lag in government oversight, consumer safeguards, and essential operational guardrails, can frustrate and possibly thwart the development of robust space-based markets. Ineffectual, or nonexistent agreements between nations risk catastrophic collisions of space vehicles and more space debris, further increasing the odds for collisions, and more debris. Even more debris spoil choice orbital locations when nations test weapons designed to disable or disintegrate satellites and other space traveling objects of enemies.

The ability of space ventures to offer faster, better, smarter, cheaper, and ubiquitous services, largely depends on the United Nations ("UN") and the International Telecommunication Union ("ITU"). These intergovernmental organizations have treaty-level responsibilities to administer, register, and manage space and radio spectrum resources. However, they currently lack any legal capacity to foreclose or remedy imprudent and harmful uses of space resources that could trigger "the tragedy of the commons" rendering the most valuable regions unusable. Both unintended and intentional actions by just a few irresponsible parties can frustrate and possibly foreclose the global consensus that space should remain a shared resource available for peaceful purposes that benefit everyone.

III. Ineffective Safeguards

Currently, the UN and ITU cannot reverse the increased risk of satellite collisions, caused by proliferating space debris. These intergovernmental agencies lack authority to require disposal or reuse of space objects, including no longer usable satellites and rocket parts that have completed a role in a staged ascent. If parties do not responsibly ensure that discarded space objects are ejected farther out into space, or on downward trajectories guaranteeing complete vaporization before reaching earth, then space will become increasingly a polluted and risky environment.

Space debris qualifies for the derogatory term space junk, because abandoned material has the potential to collide with quite valuable resources, such as operational satellites, space stations, and launch vehicles carrying astronauts, tourists, and cargo. Worse yet, nations, keen on private exploitation of space, but also "weaponizing" it as a new theater of warfare, appear inclined to disregard responsibilities they embraced when acceding to the global space treaties. The risk of costly calamities in space rises at an alarming rate.

IV. Chronic and Emerging Challenges to Space Commerce

The UN and the ITU, as well as national governments, face the daunting task of calibrating their oversight so that effective rules of road and enforcement mechanisms apply without creating disincentives for investment and innovation in space markets. Set out below, are ongoing and new quandaries requiring immediate resolution.

A) Chronic Challenges

1) Balancing Equity and Efficiency

Despite its vastness, only a small sliver of space offers an attractive value proposition to potential investors. The narrow geosynchronous orbital arc, in outer space, supports satellite delivery of video programming, including direct-to-home television. Within inner space, a relatively small sliver provides the best balance in proximity to earth and the number of satellites needed to provide service. Starlink, Viasat, One Web, Project Kuiper, Iridium, Globalstar, and Orbcomm, offer, or plan to provide voice and broadband data services, via large constellations of LEO satellites. To prevent radio signal interference and collisions, LEO operators agree to disclose and coordinate the orbital planes of their small satellites with other LEO networks and with operators of higher geosynchronous orbiting satellites that might experience interference from signals aimed as satellites in lower orbits.

The UN and ITU maintain registries of space vehicle launches, orbits, and radio spectrum uses with an eye toward reducing the likelihood of radio signal interference and collisions. Satellites and other vehicles, such as space stations, must operate in orbits that are sufficiently separated from other fast-moving objects. Most orbiting objects have limited, if any, defenses against attacks that physically dislodge, destroy, or push the object out of orbit, and attacks from space or earth that achieve the same outcome without physical intrusion, e.g., high powered lasers. Currently, earth-based monitoring, tracking, and predicting the future trajectory of space objects is limited.

Developed countries have accrued a first mover advantage, with early access to the best orbital locations, unimpaired by concerns about congestion and collision. Inter-governmental organizations have to consider what accommodations developing countries deserve, because space constitutes a resource that must be shared ("res communes") by all nations that have made treaty-level commitments to support exclusively peaceful undertakings for the benefit of all Accordingly, the UN and ITU seek to balance the ability of market forces to maximize efficiency and deployment of satellites with equity concerns that could reserve orbital slots for developing nations to use in the future.

2) Non-Enforceability, Ambiguities, Staleness, and Obsolescence in the Five U.N. Space Treaties

Soon after the onset of space exploration, but without revisions reflecting technological and market changes, the nations of the world sought to establish a global consensus on access to, and use of space resources. Five space treaties create a non-enforceable framework establishing principles including: the non-appropriation of outer space by any one country, a commitment to refrain from using space weapons, freedom of space exploration, liability for damage caused by space objects, the safety and rescue of spacecraft and astronauts, prevention of harmful interference with space activities and the environment, notification and registration of space activities, and promoting scientific investigation and access to natural resources in outer space. These agreements emphasize international cooperation to ensure that outer space activities enhance the well-being of all countries and humankind with the anticipation and resolution of conflicts.

Having no compulsory obligation to refrain from generating more space debris and to recover already generated waste, only a few Member States, including the U.S. and the European Union, have established specific mitigation requirements with an eye toward ensuring compliance, instead of aspirational goals contained in the space treaties. For example, in 2023, the U.S. Federal Communications Commission ("FCC") fined Dish Network $150,000 for failing to properly deorbit and relocate a direct broadcast communications satellite reaching end of life.

The space treaties were negotiated and finalized when few nations had become spacefaring and no private venture had begun to develop commercial market segments. Accordingly, the UN documents rely on Nation States, not private ventures, to negotiate and resolve any dispute. Commercial ventures now dominate many major markets segments, including launch and satellite services. Complex arrangements often differentiate who launches, operates, and manages space vehicles. For example, a private U.S. venture might contract with the European Space Agency and its French member, CNES, to launch a satellite from a facility in French Guyana for global services offered by a company registered in Bermuda.

The authors of the space treaties could not possibly "future proof" the documents by anticipating all ensuing developments in technology and markets. Accordingly, there exists significant uncertainty about whether and how both major and minor elements in the treaties apply. For example, it will become increasingly difficult to balance a clear commitment toward peaceful and shared access to space resources, with state actors considering space a likely new theater of warfare, locus for colonization and assertion of sovereign control, and potential resource for private financial gain.

3. Slow and Contentious ITU Consensus Building on Spectrum Allocations and Satellite Orbital Locations

Founded in 1865, the ITU holds the longevity record among intergovernmental organizations now affiliated with the UN. It has a broad mandate to manage the global use of radio spectrum by allocating frequency bands, ensuring that operators avoid causing signal interference, and registering a nation's satellite orbital slot and spectrum uses. The ITU has earned a favorable reputation for lending its "good offices" to reach global consensus on spectrum and satellite issues, albeit one that can take years to complete.

The customary course of spectrum planning and management at the ITU involves a sequence of activities: 1) development of an agenda of new allocations and reallocations, first subject to study and analysis; 2) opportunities for national delegations to articulate their position; 3) consensus building and development of national commitments, to reduce the number of non-conforming footnotes to specific spectrum allocations by individual nations; 4) formal designation of frequency allocations for one or more specific services by the ITU and individual nations; and 5) the eventual registration of radio spectrum uses and satellite orbital locations by the ITU.

Currently, the ITU convenes month long spectrum planning conferences every fourth year. Typically, final decisions on major spectrum allocation matters occur only after two or more World Radiocommunication Conferences have convened, because the ITU patiently seeks consensus among the various stakeholders. The potential for delay in reaching closure increases when representatives raise concerns not typically addressed by the ITU, nor directly related to management of spectrum and satellites. New and controversial topics include national security vulnerability of domestic telecommunications networks to espionage and disruption by foreign governments and their commercial agents, more aggressive assertions of national sovereignty, and efforts to expand oversight to include Internet access and cybersecurity.

B. Emerging Challenges

1) The Tragedy of the Commons and Kessler Syndrome from Congestion and Proliferating Space Debris

Spacefaring nations and private ventures conceptually understand the societal benefits accruing from coordinated, shared use of such scarce resources, such as satellite orbital slots and the trajectory of LEO satellite orbits. However, each operator has an incentive to maximize individual benefits, leaving others to conserve and refrain from overconsumption. If too many satellite operators opt to serve individual interests, everyone will suffer when congestion reaches a tipping point where signal interference and the risk of collision becomes unmanageable.

Economists use the term "tragedy of the commons" to describe how self-serving individual consumption of a shared resource generates overconsumption eventually leading to depletion and possibly complete ruin. For example, if a government offers public land for cattle crazing at little or no expense, each rancher has an incentive to increase the number of animals consuming vegetation, an exhaustible, shared resource. At some point, overgrazing depletes the soil, and the entire flock of cattle may starve.

Users of space resources risk a similar tragedy from overconsumption and wasteful generation of space debris. The Kessler Syndrome refers to the worst-case scenario when too many satellites and other space objects occupy the same space region, resulting in radio signal interference, an unmanageable risk of space vehicle collisions, and the proliferation of debris generated by inadequate disposal or recycling of satellites and other space objects after they become unusable.

By abandoning space debris instead of relocating it farther out in space, or vaporized on its way back to earth, users of space resources create a potential catastrophic environmental hazard that increases the operating costs of every spacefaring nation and private venture. Proliferating space debris increase the risk that an operational and valuable object, like a multi-million-dollar satellite, may collide with an equally valuable asset, or more likely, become inoperable and a total financial loss due to a collision with one many abandoned and valueless objects, still orbiting in space.

"Space junk," can collide with operating satellites and space stations causing irreparable harm, as well as increasing the premiums paid by operators to insure satellites. Even tiny pieces of space debris, having little size and weight, but tremendous destructive power, can render vast portions of outer space unusable. The region where LEO satellites operate has the greatest potential for further commercial development, but also the largest deployment of satellites and the largest number of abandoned space objects, such as used but not retrieved rocket launch stages weighing several tons. With so many space objects located in a relatively small portion of space, the possibility of collisions grows, as does the potential for even more space debris.

2) Space as a New Theater of War—Anti-Satellite Weaponry

Arguably, ASATs in space constitute the most egregious and avoidable cause of the growing threat from space debris proliferation. China, India, Russia, and the U.S. have tested ASAT technology, often with quite harmful results. A single, test, lacking space debris prevention or mitigation, can result in thousands more objects requiring constant monitoring. For example, a 2021 Russian ASAT test, targeting a defunct LEO satellite, generated 1500 new pieces of trackable debris, 10 centimeters in diameter or larger. The test occurred just 48 miles above the International Space Station, triggering the execution of emergency avoidance maneuvers.

ASAT-generated space debris significantly increases the likelihood that two space objects will collide. It raises the odds that space will become a toxic and risky environment where collisions become a more frequent event. Bear in mind that when a collision occurs, more debris surely follows. In February 2009, the defunct Russian Kosmos 2251 satellite slammed into an operational communications small satellite operated by Iridium. The Russian government offered no compensation for ruining a working commercial asset, and the collision created an estimated 2000 additional debris objects, the size of a softball or larger.

3) Space Resource Exploitation for National and Private Gain, e.g., Colonization of the Moon/Mars and Asteroid Mining

Consistent with its characterization as a frontier, a gold rush urgency has motivated entrepreneurs to pursue a variety of commercial business plans that might previously have been dismissed as science fiction fantasy. Three of the world's richest and newsworthy individuals already have invested millions of dollars in LEO satellite networks and new launch vehicles. Along with others, they contemplate the future development of new commercial markets for space tourism, extraction of valuable minerals, and colonization of the Moon and Mars.

Commercialization of space can coexist with the constraints established in the space treaties. However, the potential for conflict and overreach constitutes a legitimate concern. On one hand, there are examples on earth where private appropriation of a shared natural resource comports with international law. Private ventures, operating in international waters, can acquire fish, abandoned treasure, and oil, gas, and minerals in full compliance with applicable treaties. On the other hand, we cannot ignore the incentive of first movers to foreclose others from sharing access. One nation's peaceful creation of an outpost on the Moon for exploration and discovery in practice could evolve into the assertion of sovereign control and ownership.

Currently, one can only speculate how national governments and private ventures will behave. It does appear that the space treaties and applicable international law do not fully establish the rights, responsibilities, options, and limitations applicable when governments and private ventures seek to extract value from shared space resources. The UN cannot expect nations to comply with a voluntary moratorium on space exploration and resource extraction pending enactment of new, or significantly modified treaties.

V. The Way Forward

Despite much uncertainty about how space markets will evolve, several issues already require resolution to provide clarity about best practices, and reasonable interpretation of existing treaties and laws. Set out below are recommendations on how the UN, ITU, and individual governments can promote robust and globally beneficial space commerce.

A. Timely Revisions to the Space Treaties

The space treaties came into force during the period from the middle 1960s to the late 1970s. They require substantial updating to reflect substantially changed circumstances, highlighted by the commercialization of space market segments by private ventures. These challenges require affirmative and enforceable duties of care by signatory nations and commercial ventures, not a general appeal to their better nature.

1) Recognition of Private, Non-State Actors

Private space market entrants deserve recognition in the space treaties with conferral of specific rights and responsibilities. Transactions often involve multiple participants, including one or more national governments, private ventures, and/or public-private partnerships. For example, an operating satellite might have different parties involved in the launch, ownership, operational management, and license acquisition. Currently, the space treaties confer rights and responsibilities on "State Parties" which have acceded to the agreement with emphasis on the national government launching or procuring the launch of a space object.

The space treaties should explicitly recognize private ventures operating in space by conferring rights and responsibilities previously applied only to national governments. If a private venture's owned and operated space object collides with, and damages another space object, the private venture should bear financial responsibility to compensate the harmed public or private entity.

2) Treaty Enforceability

The space treaties create affirmative responsibilities on signatory nations, but impose no sanctions for noncompliance. Because the consequences will substantially rise when nations fail to comply with treaty responsibilities, the nations of the world should amend the space treaties to specify penalties for noncompliance. For example, a nation, or private party, deemed responsible for damages caused by a collision of space objects should lose the rights conferred by the applicable treaty until such time as it accepts responsibility and satisfactorily compensates the harmed party. The space treaties also should establish a mechanism for dispute resolution through an adjudication or binding arbitration process.

3) Monetary Commitments to, and Bounties for Debris Prevention, Mitigation, Collection, and Disposal

Ideally, public and private ventures owning and operating space objects, such as satellites, should incur the responsibility to deposit funds into an account that could be tapped to compensate other ventures harmed by a collision, or impact from space debris abandoned by a known party. Such an escrow account also could provide a bounty for ventures that collect and dispose of space debris. It already has become clear that a public or private venture clearly responsible for causing a collision may not voluntarily compensate the harmed party, despite clear evidence of culpability. Recently, a homeowner sought compensation from NASA for roof damages caused by used batteries dumped from the International Space Station.

For commercial space markets to operate smoothly and efficiently, participants need uniform rules of the road, including binding laws and treaties. Private insurance options will become prohibitively expensive if collisions increase and market participants cannot rely on the space treaties to establish compulsory procedures for resolving disputes with guaranteed financial compensation flowing to harmed parties.

The space treaties should clarify that spacefaring nations and private ventures have a duty to dispose of objects, rather than abandon them. National regulatory authorities, such as the FCC, now require licensees to eject geosynchronous satellites, reaching end of mission, into locations at or beyond a specified distance from their original orbit. The FCC also requires operators of LEO satellites to eject them from orbit within five years of their completed missions. Additionally, spacecraft launching parties should bear an obligation to ensure that booster stages and other parts are properly disposed or recycled. SpaceX already uses maneuvers to return launch boosters back to earth for reuse.

4) Curbing Weaponization of Space Conflicts with Reaffirmation of Treaty-level Commitments to Peaceful and Shared Uses

Ever growing deployment of satellites into space creates rising incentives to devise ways to disable and destroy them during times of war. Weaponization of space started with the testing of ASAT technologies from both earth-based and in-orbit tactics. These weapons can target military, surveillance, commercial, and other networks that provide essential infrastructure supporting both national security and private welfare. Some national governments appear unwilling to abandon testing and use of space weaponry, despite having previously committed to the peaceful use and shared access to space resources. For example, in 2023 and 2024, Russia launched two satellites that appear to have nuclear ASAT weaponry and the ability to maneuver to target specific satellites.

Notwithstanding the weaponization of space, national governments should reemphasize the primary purposes for space use. Most nations will never become spacefaring. Even though these countries do not directly tap space resources, their residents benefit when public and private operators provide services that enhance public and individual welfare.

Cascading toward the Kessler Syndrome threatens a substantial decline in the global economy and individual wellbeing. Accordingly, the nations of the world should reaffirm that space is too precious to be ruined by the proliferation of debris and other unilateral and harmful activities of individual nations. Fundamental fairness requires nations, first able to tap new market opportunities, do not render future access impossible, limited, or more expensive.

5) Clarity in Mission and Better Coordination of Responsibilities Between the U.N. and ITU Versus Creating Domestic and International Digital Authorities

On the global, inter-governmental level, the UN and ITU share jurisdiction with the former responsible for administering the space treaties and registering all launched space objects and the later handling spectrum allocation and registration of radio licenses and orbital slot assignments made by national regulatory authorities. While the agencies have a clear division of responsibility for core registration and administrative functions, much uncertainty arises on new matters such as the proliferation of space debris. Both the UN and ITU have undertaken comprehensive analysis of threats from space debris, but more proactive and comprehensive oversight is long overdue.

The UN and ITU need to combine their ongoing passive registration processes, with proactive identification of solutions to chronic and emerging challenges. Clearer mandates from revised space treaties are essential, but inertia and conflicting national motivations may preclude any timely reform. In the interim, the UN and ITU should interpret their missions more expansively and negotiate a clear division of responsibilities.

VI. Conclusions

Despite the comprehensive and conscientious efforts of the UN, ITU, and national space agencies, individually and collectively, the lack of enforceable requirements severely limits progress. Without "skin in the game," financial responsibility, parties launching and operating space objects will not have sufficient incentives to refrain from generating more space debris, or to remove existing waste. Stakeholders incur strong incentives to change their behavior when they have to post bond or contribute to an escrow account, and when they have a compulsory duty to compensate parties they have harmed in space. When parties can qualify for a bounty for removing space debris and for meeting compliance requirements, they will have compelling financial incentives to use best practices. The availability of monetary inducements can stimulate the development of a market for collection, disposal, and possible recycling of existing space debris.

Simply put, space debris challenges have become acute problems requiring immediate attention rather than further study and appeals to good space citizenship. International law must establish clear and enforceable duties of care by spacefaring governments and private ventures.

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POLICY AND REGULATORY ACTIONS REQUIRED TO DELIVER TRUE 5G

BY STEFAN ZEHLE, CEO, COLEAGO CONSULTING

5G mobile is a set of requirements and features which go well beyond 4G

IMT-2020 (5G) is to provide ubiquitous high-speed wireless mobile connectivity to support several use-cases: "*IMT-2020 is expected to provide a user experience matching, as far as possible, that of fixed networks*"[1]. 5G must deliver a near guaranteed user experienced mobile data rate of 100 Mbit/s in the downlink and 50 Mbit/s in the uplink and accommodate 1 million connections per km^2 [2].

5G is designed to deliver a reliable user experience for smartphone users and other applications in terms of speed. In other words, coverage must be defined as 'speed coverage'. If the user experienced speed is insufficient for the application, it is the equivalent of not having true 5G coverage. While in mobile networks there can never be a guarantee of speed, the implication is that there must be a very high probability of achieving the speed. Arguably with most of today's applications, 100 Mbit/s DL is not required - 20 Mbit/s would be a reasonable speed for the vast majority of applications as of early 2025. Yet in many places where there is 5G coverage it is impossible to hold a video call.

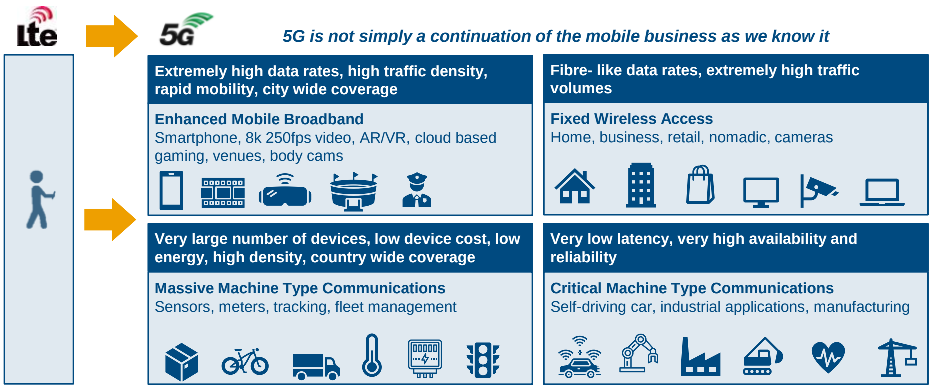
5G is not simply about speed or enhanced mobile broadband (eMBB). 5G brings a set of new features, such as network slicing, massive machine type communications (mMTC), and Ultra-Reliable Low Latency Communications (uRLLC). These 5G features are only available in a 5G-Stand Alone (5G-SA) network. In other words, 5G Non-Stand Alone is not true 5G.

5G and 6G mobile networks are an enabling platform for all use cases and applications. The development from 4G (LTE) to 5G (IMT-2020) has already seen an expansion of requirements to cover a wide range of use cases and applications. While 4G can be thought of as a best effort mobile data service for smartphones, 5G addresses a wide range of use

cases and with new capabilities such as low-latency, network slicing, and ultra reliability. In essence, a mature 5G network is a platform which addresses all present use cases.

Expansion of use cases with 5G

[1] Report ITU-R M.2441-0 (11/2018), "Emerging usage of the terrestrial component of International Mobile Telecommunication (IMT)"
[2] Report ITU-R M.2441-0 (11/2018)



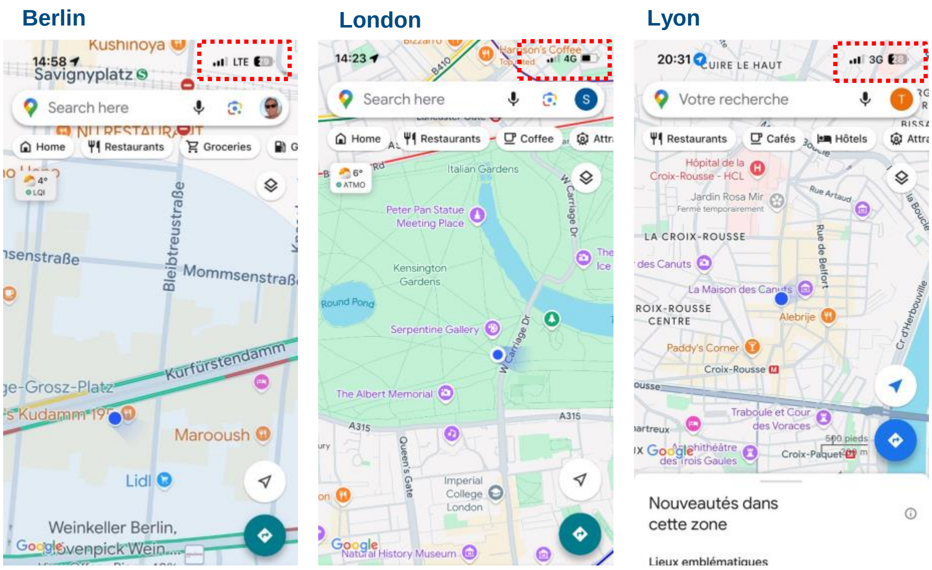
5G coverage holes in urban areas and 5G-SA availability should become a focus for regulatory action

Governments around the world have a clear policy to ensure that 5G connectivity is available to consumers, industry, agriculture, and institutions of all types. In supporting the deployment of 5G in their countries, policymakers agree that 5G is an essential enabler for the digital transformation of their countries. Governments congratulate themselves on achieving population coverage targets - for example, the European Commission's 5G Observatory claims 89% 5G population coverage in EU countries as of mid-2023[3].

The first problem is that this claimed 5G coverage relates to 5G Non-Stand Alone, i.e. hybrid 4G – 5G. 5G-SA coverage is patchy and hence services which require 5G-SA, such as network slicing are not consistently available.

The second, bigger, problem is that the claimed 5G coverage is not true and hence misleads policymakers, which leads to sub-optimal policy choices. The 89% coverage figure includes contiguous urban areas but does not take account of the fact that there are substantial 5G coverage holes outdoors and in indoor public spaces such as shops, restaurants, and public transport stations. The chart "5G coverage holes in European cities" below shows screenshots taken with 5G enabled phones in central parts of three cities outdoors in places where there the 5G smartphone could not connect to 5G.

5G coverage holes in European cities



Source: Screenshots from 5G enabled smartphones, January 2025

Coverage obligations focus on rural coverage. In some cases, regulators attach a rural roll-out obligation to mid-band spectrum. Not only is it costly to deploy a rural site but this site will carry very little traffic. If instead the money was spent to create truly contiguous 5G coverage in urban areas this would benefit many more people and businesses activities. In other words. A Euro spent on 5G urban coverage generates a far higher socio-economic benefit than a Euro spent on 5G rural coverage.

[3] 5G Observatory Biannual Report, June 2024

The misguided focus on rural coverage targets which, for example requires German mobile operators to deploy 3500 MHz sites in the middle of nowhere, is a waste of money. Investment in indoor coverage in cities would benefit more people more of the time and would generate a higher socio-economic benefit than incremental coverage to ever more remote areas.

In less developed countries, the policy focus on covering remote rural locations with terrestrial 5G is particularly harmful. This is because the affordability gap, i.e. people not being able to afford 5G mobile devices as a percentage of the population, is greater than the coverage gap: Only 4% of the global population are not covered by mobile broadband but 42% do not use it[4], with lack of affordability being key reason. Furthermore, the more rural a location is, the lower household incomes and hence the affordability gap becomes wider the more 5G coverage is pushed out into rural areas. What is the point of building 5G coverage in a village where nobody can afford to use it? Building remote rural 5G sites is costly and pushes up operator costs. Higher costs translate into higher retail prices, which impact negatively on affordability. Closing the usage gap is estimated to add $3.5 trillion in total additional GDP between 2023–2030. "*More than 90% of this benefit ($3.2 trillion) would accrue to LMICs, given they account for the vast majority of the unconnected*"[5].

A far more cost-effective solution to lack of rural coverage would be direct-to-device (D2D) satellite connectivity. Within the next three years we will see D2D for data and voice as well as SMS. D2D will provide a true 100% geographic coverage in rural areas which could never be achieved with terrestrial mobile networks. Policymakers should take this into account when setting rural coverage requirements for mobile operators.

Lack of consistent 5G coverage and 5G-SA availability supresses 5G use

European policymakers focus on arbitrary headline speed goals. Yet, in most European cities there are substantial 5G outdoor coverage holes with poor capacity, even in central areas. If applications such as streaming, video telephony, or simply looking at a map with satellite image detail do not work properly, then this amounts to having no coverage at all. Today's 5G networks in cities, where most people live and work, do not even come close to ITU-R's requirements for 5G (IMT-2020). It is highly likely that demand - i.e. what people and businesses want to do - is constrained by the lack of area network capacity (speed coverage). If people could actually use their smartphones reliably anywhere, anytime, usage is likely to increase substantially.

The inability to make a WhatsApp video call may be an inconvenience, but applications relying on consistent speed may not work at all. For example, equipping first responders and other field operatives with body-worn cameras where the livestream is analysed on an AI platform must work reliably outdoors and indoors. Unless 5G speed coverage reaches a level of reliability in terms of consistent speed and ubiquity, potential users may be reluctant to make the investment and adapt their operations to reap the benefits of such application.

For businesses, municipalities, and public services the lack of ubiquitous speed coverage may be a deal-breaker. How can a business or municipality build a process or service which relies on 5G connectivity when in urban areas there are 5G-NSA coverage hole and only patchy 5G-SA coverage? That is not what 5G is meant to be.

5G traffic would increase significantly with consistent 5G speed coverage and unlimited tariffs

Unlimited pricing coupled with consistent 5G availability will have a fundamental impact on smartphone user behaviour. With unlimited 5G tariff plans the marginal cost of using mobile data on 5G is the same as on Wi-Fi, i.e. zero. If there is good speed coverage, why would anyone bother switching to Wi-Fi in a shop when it would not require any effort to stay on 5G mobile with the added benefit of a secure connection.

In Finland mobile operators have implemented 5G-SA and sell a user experience in terms of speed (Mbit/s) as opposed to data volume (Gbytes), i.e. the cost of an incremental Gbyte is zero. As of October 2024, Elisa Finland offered a speed of 300 Mbit/s with unlimited data volume for €34.99. By contrast, in Germany, Telekom's offer for 20 Gbytes is priced at €39.95 per month. For unlimited data usage Telekom charges €84.95, which is 2.5 times more costly than Elisa's unlimited offer.

Finland reports that between January to June 2024, monthly mobile data consumption per capita was 74 Gbytes, with roughly half of that from smartphones and half from data-only devices[6]. In Germany, the average monthly data usage per mobile customer (rather than per capita) amounted to 7.4 Gbytes and this may have risen to around 8 Gbytes in 1H 2024. In 2024, mobile data consumption in Finland

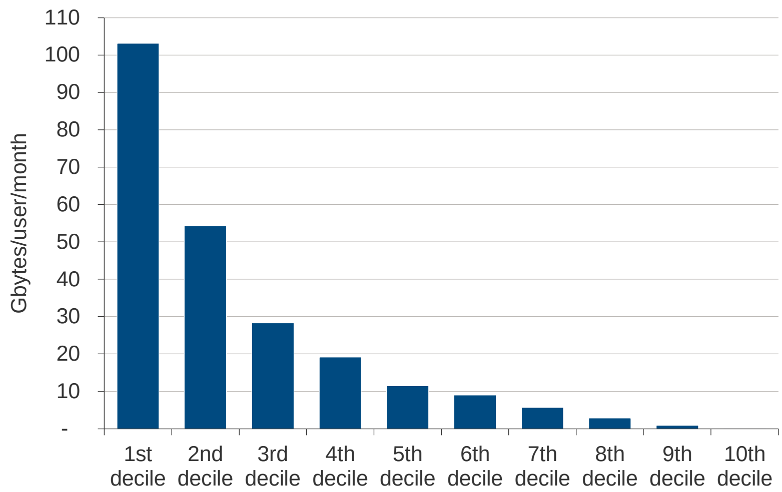
[4] The State of Mobile Internet Connectivity 2024, GSMA
[5] The State of Mobile Internet Connectivity 2024, GSMA
[6] TRAFICOM, 1 Oct 2024

was around ten times higher compared to Germany. Surely, if prices in Germany were like those in Finland, monthly mobile data usage per customer would be much higher.

There is clear evidence that mobile data consumption on smartphones is likely to grow to beyond 100 Gbytes/user/month.

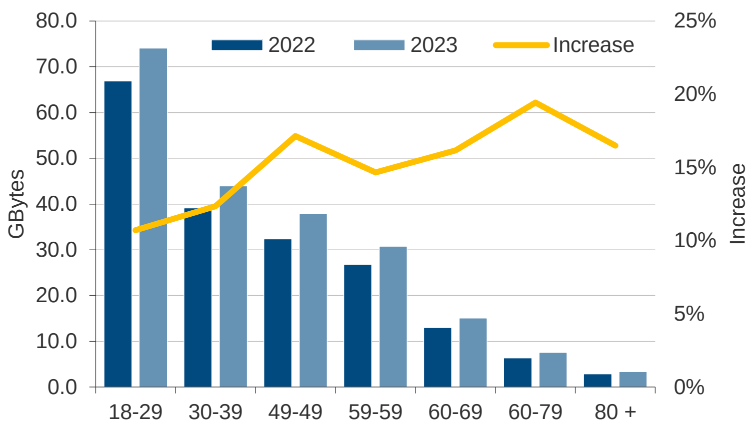
The top decile of smartphone users already consumes in excess of 100 Gbytes per month. Analysing monthly data usage in a mobile network by 10 percentiles, the top 10% of users typically account for 35-45% of data usage with consumption of five times the average or more, often in excess of 100 Gbytes per month. This shows that it is possible, even with today's applications, that at least some smartphone users generate 100 Gbytes of data or more. The most relevant variable in explaining these differences in monthly mobile data consumption is the age of the user. For example, a study by the Finnish mobile operator DNA found that on average, adults under the age of 30 use 74 Gbytes per month on their smartphones (excluding FWA) compared to 44 Gbytes in the 30-39 age group, 38 Gbytes in the 40-49 age group and less in each older 10-year cohort[7].

Gbytes per mobile user per month by decile



Source: A European mobile operator

Gbytes per mobile user per month by age group



Source: DNA, Finland

Due to the lack of 5G speed coverage, including indoor public spaces coupled with volume-based pricing, smartphone users often spend more time connected to Wi-Fi in public places rather than 5G mobile. As an illustration, Australia's smartphone users spend on average

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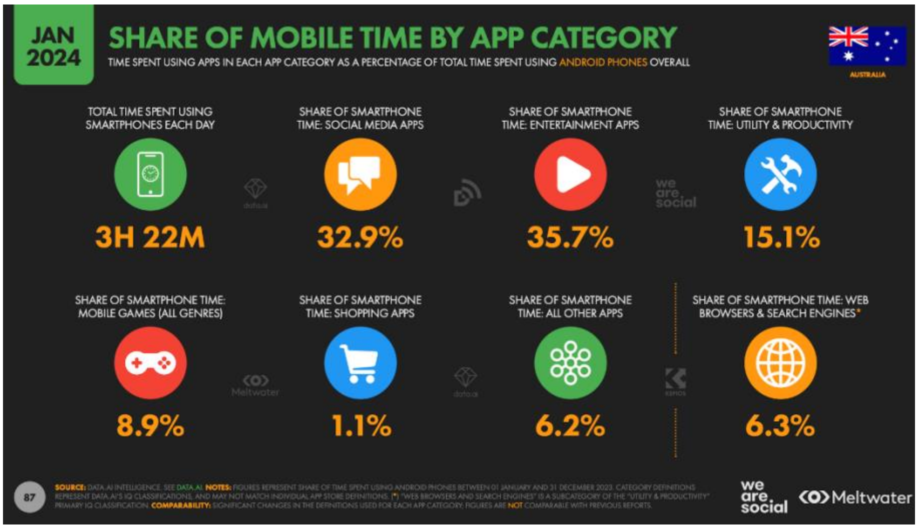
[7] DNA press release, 12 December 2023, figures reported as daily average converted to monthly averages (30 days/month)

3.22 hours per day using their smartphones and 35.7% (1.15 hours per day) of this is entertainment (video) use[8]. Most of this is carried by Wi-Fi, but it demonstrates that once smartphone users are no longer constrained by mobile bandwidth availability and volume-related pricing, 5G mobile traffic would increase substantially. Assuming that 50% of today's daily usage i.e. 34.5 minutes would be via 5G mobile at 20 Mbit/s (HD YouTube video) this would generate a monthly data volume of 158 GB just on mobile video.

Smartphone traffic by app category



Source: 2024 Social Media Statistics for Australia, Jemma Healy, Meltwater, Apr 29, 2024

Focus on delivering a true 5G user experience

While there is much talk about data volumes, the focus on forecasting data volume is misplaced - 5G is about delivering a user experience. As yet, in most countries 5G is disappointing, but this is primarily because most mobile operators have not delivered the requirements for 5G (IMT-2020) as set out by the ITU[9], namely to provide a 100 Mbit/s user experienced data rate in the downlink and 50 Mbit/s in the uplink, anytime, anywhere and while 'on the move'. History teaches us that data usage is largely supply driven.

The high data usage in Finland is not only linked to price but also to the quality of the network: 5G actually works well. Contrast that with the experience of mobile users in London. Upon exiting an underground station, the wait for Google maps to load can be 30 seconds or longer if the satellite map type is selected. Attempting to load a discount voucher to the supermarket loyalty app at the checkout is extremely slow and often tends not to work at all due to poor mobile connectivity, and discussing an intended purchase on a WhatsApp video call rarely works. Approaching a bus stop in Berlin, you may find it very slow to activate a ticket on the app because people waiting at the bus stop are busy watching things on their smartphones causing area traffic demand (Mbit/s/m2) to exceed area traffic capacity. Commuters on the London underground have no coverage in tunnels and slow connection speeds in stations. Yes, they can download a newspaper before leaving for work, but they cannot watch the morning TV news during their 20-minute commute.

There is nothing esoteric here - these are mundane applications which do work well. If there was ubiquitous reliable 'speed coverage', people could make much more use of their smartphones.

Demand for mobile bandwidth will increase

Bandwidth demand is likely to increase. Looking at the video setting on an iPhone 12 Pro, the highest quality setting 4K with 60 frames per second would use 440 Mbytes per minute. That is a data rate of 20 to 80 Mbit/s depending on compression.

The human ability to perceive quality watching a video on a small screen is one criterion. However, users may want to zoom in on a football tackle without pixelation and look at it in slow motion, both of which require higher resolution or higher frame rate and hence a higher bandwidth. Security applications can be far more demanding. AI analysing a security camera video stream may identify a suspect

[8] 2024 Social Media Statistics for Australia, Jemma Healy, Meltwater, Apr 29, 2024
[9] Report ITU-R M.2441-0 (11/2018), "Emerging usage of the terrestrial component of International Mobile Telecommunication (IMT)"

person. However, the alert to the control room is only triggered when AI zooms in on the person's hand to see whether the individual holds a folding umbrella or a gun. For streaming at higher resolutions, higher bandwidths are required.

A key aspect of the ITU vision for 5G is that it addresses business and institutional uses. New features, such as network slicing, enable new use cases. For example, the Kaohsiung City Police Department in Taiwan operates a 'smart patrol car' using a network slice on a 5G-SA network to support licence plate recognition. With this application, patrol cars equipped with high-resolution cameras use an AI image analysis solution to identify vehicles that have been reported stolen.

Regarding new features, notably network slicing, consistent speed coverage, including indoor coverage, is a requirement for many use cases. This ranges from asset tracking (which does not require a lot of bandwidth) to cameras worn by first responders and other field operatives. Live streaming by body-worn cameras is not some futuristic application, it is already being implemented. Live streaming body cameras can give a rapid indication to control rooms about the risk level of a situation. The live streams will be analysed by AI triggering alerts for control room intervention when needed. Whilst currently only a small percentage of workers are equipped with this technology, this is only one application that would rely on the ubiquitous mobile speed coverage, outdoors and indoors.

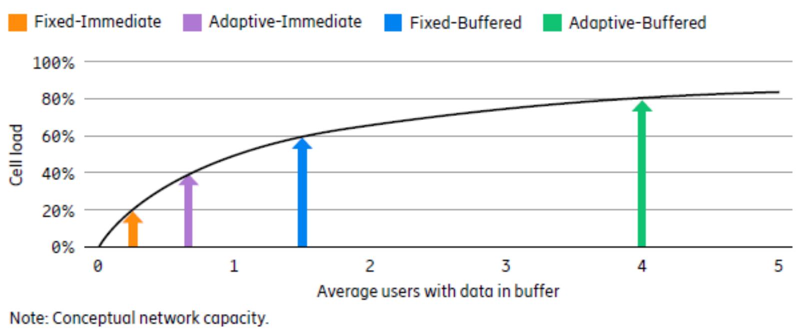
There are an estimated nine million CCTV cameras in the UK. Cameras could be hooked up by wire or Wi-Fi, but it is much more flexible and convenient to use 5G connectivity. Convenience is of course a major driver in mobile and Wi-Fi connectivity. Convenience is also why many 5G mobile users - provided that there is good speed coverage - no longer bother with Wi-Fi even at locations where is it free. Why would a consumer log onto multiple Wi-Fi networks while shopping on a high street instead of benefiting from seamless 5G coverage indoors and outdoors?

Additional mid-band spectrum is required to deliver reliable speed coverage

In cities, the greatest cost to mobile operators is to provide capacity. When busy hour traffic increases, operators split macro sites or install small cells to provide additional capacity. Good mobile networks maintain a capacity headroom in each cell of 30%, i.e. the busy hour physical resource block (PRB, the smallest unit of capacity in a mobile network) loading reaches 70%. However, if speed must be delivered reliably, the trigger for capacity additions would need to decline to perhaps 50%. This shows that irrespective of data volumes, there is a cost to delivering a reliable user experience.

Some applications require performance. In the November 2024 Mobility Report, Ericsson highlights the issue: "*Wireless data transmission can be categorized into four distinct performance classes based on if the size of the data can be adjusted (fixed or adaptive) and how quickly data needs to arrive (immediately processed or buffered before use). There is a different level of cost associated with delivering data across these classes. The chart shows the conceptual network capacity required to deliver streams of traffic via different performance classes. Generally, when it comes to supporting connections with higher requirements on latency, the effective load on the network to deliver the connection needs to be lower. This means that to support traffic in more demanding performance classes, the effective network capacity needs to be higher. This increase in capacity has direct cost implications. More network resources must be allocated to maintain the characteristics required for premium connectivity services. Thus, service providers should factor in these increased costs when planning and managing their networks to offer differentiated connectivity services.*"[10]

Dimensioning the network for different performance classes



Source: Ericsson Mobility Report, November 2024

[10] Ericsson Mobility Report, November 2024

It is clear that the economics for delivering a consistent user experience are challenging. Using more spectrum is cheaper than building new sites. Making additional mid-band spectrum, notably 6475-7125 MHz, available for mobile makes it much more feasible for operators to deliver a 5G service which meets the IMT-2020 vision for fibre-like connectivity anywhere, while on the move.

Policy action is required to facilitate small cell deployment

In urban areas outdoor and indoor small cells are required to provide sufficient area traffic capacity to serve all 5G use cases. Small cell densification is mostly driven by the need to improve the user experience in places where macro sites do not provide sufficient speed coverage.

Often planning rules or excessive site rental prices hold back small cell deployment. Enlightened municipalities have recognised the benefit of excellent speed coverage and offer municipal infrastructure such as lampposts for small cell installation for a nominal site rental. For example, the London borough of Lewisham offers lamppost for GBP 50 per year.

Assuming operators share small cells, perhaps equipped with 700 MHz of spectrum in the upper 6 GHz band (6425-7125 MHz), the annual total cost of ownership (TCO) per site could be GBP 5,000. To put this into perspective, in 2023 UK mobile operators paid around GBP 320 million in annual spectrum licence fees, an amount which could pay for 64,000 small cells.

Indoor deployments are part of the densification story, with neutral host installations gathering momentum. Most public indoor venues such as shops, restaurants, transport hubs, etc. offer Wi-Fi to their customers. If the venue owners cooperated with mobile operators to allow them to install 5G small cells such as Ericsson's Dot. in the form of a neutral host solution, this would change the economics of indoor 5G coverage. Businesses would save on the cost of owning and operating Wi-Fi on their premises and hence could forgo mobile site rental fees and not charge for electricity. There are synergies - having 5G-SA coverage indoors can be of great benefit to shops, for applications such as asset tracking and using an indoor network slice. For example, the Ericsson 5G Precise Positioning for indoor networks with Ericsson Radio Dot allows accurate location tracking.

Regulatory intervention could extend to mandating indoor 5G coverage. This could be done using wayleaves legislation or imposing a requirement on premises owners. After all, there are many regulations which oblige premises owners to install equipment such as fire alarms and other environmental sensors.

Transition to public interest spectrum pricing

Holding spectrum auctions or charging for spectrum licence renewals is increasingly inappropriate in a world where mobile use has shifted from a luxury product to an essential tool for individuals and business processes. 5G-SA is the connectivity glue for the digital transformation of nations. Taxing this transformation in the form of spectrum licences fees is not in the public interest. Policy focus must shift from extracting spectrum licence fees towards ensuring that a maximum of spectrum is made available to operators in order to deliver the 5G vision in an economically feasible manner.

If governments stopped extracting billions in spectrum licence fees, perhaps more cash would flow into network investment, notably indoor and outdoor speed coverage, and we would see a virtuous circle of increasing area network capacity (Mbit/s/m2) and increasing area traffic demand. Above, we contrasted the excellent 5G mobile services on offer in Finland, where the annualised cost of spectrum accounts for less than 1% of service revenue, with Germany where it is around 10%. Low spectrum licence fees are a significant factor in Finland's 5G success story.

"*Public interest spectrum pricing*" means making mobile (IMT) spectrum licences available as early as possible and at minimal cost.

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Stefan Zehle has 30 years' experience in telecoms industry. He is the Director of a mobile operating company and specialises in strategy & business planning and spectrum issues. He gained his experience working in 65 countries on all continents and has worked on over 90 spectrum-related projects. His recent publications include the "The need for sub-1 GHz spectrum to deliver the vision of 5G", report for the GSMA (2022) and "Demand for IMT spectrum in the 2025-30 timeframe", model and report for the GSMA for WRC-23 (2021). Stefan is the co-author of the Economist Guide to Business Planning and, holds an MBA with distinction from University of Westminster, London.

About Coleago Consulting Ltd

Founded in 2001, Coleago is a telecommunications consulting and training firm. We offer an experience-based consulting approach, with project teams entirely made up of partner-level consultants, each with a minimum of 20 years' experience in the telecoms sector. Our advice is therefore based on practical experience and proven processes and methodologies developed over many years. Since 2001 we have carried out over 140 spectrum projects in developed and emerging markets on all continents.

THE AI ENERGY PARADOX: ADVANCE SUSTAINABILITY VS. CLIMATE FOOTPRINT

LEADING REGIONAL CASES FROM KSA & UAE.

BY GEORGE SALAMA, SALAMA GROUP EXEC. PRESIDENT - CO-FOUNDER AI UNIVERSAL COUNCIL.

Artificial Intelligence (AI) is the transformative force capable of solving the world's most pressing challenges, particularly in the realm of sustainability. By optimizing energy use, reducing waste, and enhancing climate predictions, AI is proving to be a powerful ally in combating environmental crises. However, the energy-intensive nature of AI systems itself raises a crucial question: can we achieve the sustainability gains promised by AI without exacerbating its own energy footprint? This paradox demands a closer look at both the contributions of AI to sustainability and the challenges posed by its energy consumption.

The rise of AI is intrinsically linked to the global push for digital transformation. Across industries, businesses and governments are leveraging AI-driven technologies to create smarter systems, optimize resources, and improve decision-making processes. For instance, AI algorithms help utility companies predict energy demand more accurately, reducing waste and facilitating better integration of renewable energy sources.

Yet, the enthusiasm for AI adoption must be tempered with an understanding of its environmental cost. The energy consumption required to train and deploy advanced AI systems is staggering, with large-scale models demanding the computational power of thousands of processors. As AI systems become more complex and pervasive, their environmental footprint grows, prompting a critical need for innovation in energy efficiency and sustainability practices.

The AI sustainability paradox underscores the complexity of leveraging technology to address global challenges. While AI holds immense promises for combating climate change, its energy demands cannot be ignored. The question is not whether AI can save the world, but whether we can save the world *with* AI. The answer lies in our ability to balance innovation with responsibility.

KSA: Strategic Focus on AI Data Centers and Green Energy

The Kingdom of Saudi Arabia's ambition to create a $100 billion AI powerhouse is exemplified by the work of the Saudi Company for Artificial Intelligence (SCAI), established under the Public Investment Fund (PIF) in 2021. SCAI's mission is to drive innovation across critical sectors by developing AI-powered data centers that are seamlessly integrated with renewable energy solutions, ensuring both technological progress and environmental responsibility.

SCAI is at the forefront of developing advanced data center infrastructure to meet the computational demands of AI applications. In partnership with global technology leaders like Google Cloud and Microsoft, these data centers are designed to optimize energy use through AI-powered cooling systems and predictive algorithms. These innovations reduce energy consumption while maintaining peak performance, positioning Saudi Arabia as a leader in energy-efficient AI technologies.

To support its energy-intensive AI infrastructure, SCAI is leveraging Saudi Arabia's vast investments in renewable energy. Projects like the Sudair Solar PV Plant, which has a capacity of 1.5 GW, provide clean and uninterrupted energy to power data centers. Additionally, advanced battery storage systems ensure a steady supply of electricity, enabling continuous AI operations without reliance on fossil fuels.

SCAI's initiatives align with Saudi Arabia's Vision 2030, which prioritizes economic diversification and environmental stewardship. By coupling AI advancements with renewable energy strategies, the kingdom is creating a resilient ecosystem that supports growth, innovation, and global collaboration. These projects demonstrate how strategic investments in AI and green energy can drive transformative change on a global scale.

UAE: Mubadala's Landmark Renewable Energy and AI Initiative

During his address at the World Economic Forum, Davos 2025, H.E. Khaldoon Al Mubarak, Managing Director and Group Chief Executive Officer of Mubadala, the UAE sovereign investor managing a diverse portfolio of assets in t he UAE and abroad of USD 302 BN assets under management, unveiled a groundbreaking project in the UAE - a $6 billion solar energy initiative. The project involves the construction of the largest gigawatt-scale solar panel energy facility in the region. The facility will deploy 5.2 GW of solar panels across 90 square kilometers and integrate 19 gigawatts of battery storage, enabling it to produce 1 gigawatt of uninterrupted base load solar power. This transformative initiative aligns with the UAE's Net Zero by 2050 objectives and underscores the nation's leadership in renewable energy innovation.

What makes this project even more significant is its synergy with the UAE's growing investments in AI enablement and data center capacity. By coupling sustainable energy solutions with advanced AI technologies, the UAE is creating a foundation for energy-efficient computational infrastructure. This dual focus not only supports local growth but also positions the UAE as a global leader in renewable energy-powered AI advancements.

The project highlights a pivotal shift toward AI-driven sustainability, with energy-intensive industries like data centers relying on renewable power to mitigate environmental impact. By integrating solar energy with AI and compute capacity, the UAE exemplifies how nations can address the global energy dilemma while fostering innovation and growth.

The Promise of AI for Sustainability

AI's potential to address climate change is immense. Here are a few examples of how AI is already making a difference:

- **Energy Optimization:** AI-powered smart grids can balance energy supply and demand in real-time, reducing waste and integrating renewable energy sources more effectively. For instance, Google's DeepMind reduced the energy used for cooling its data centers by 40% through AI-driven optimization.
- **Climate Modeling:** AI can process vast amounts of climate data to improve the accuracy of weather forecasts and long-term climate predictions. This helps policymakers and businesses make informed decisions about resource allocation and disaster preparedness.
- **Precision Agriculture:** AI enables farmers to optimize water usage, reduce pesticide application, and increase crop yields. According to the World Economic Forum, AI-driven precision agriculture could reduce global greenhouse gas emissions by 1-2%.
- **Carbon Capture and Storage:** AI is being used to design more efficient carbon capture technologies, which are critical for achieving net-zero emissions. For example, researchers at MIT used AI to identify a new material that could significantly improve carbon capture efficiency.

In addition, AI's versatility enables it to support numerous United Nations Sustainable Development Goals (SDGs):

- **Healthcare (SDG 3):** AI enhances diagnostic accuracy through advanced imaging analysis and predictive analytics, leading to improved patient outcomes. Algorithms capable of detecting diseases early facilitate timely and potentially life-saving interventions. For instance, Google Health's AI-powered tools for breast cancer detection have achieved an accuracy rate comparable to expert radiologists, reducing diagnostic errors and improving early detection rates.
- **Education (SDG 4):** Personalized learning platforms powered by AI cater to individual student needs, promoting inclusive and equitable education. Systems like IBM's Watson Education adapt to diverse learning styles and provide teachers with actionable insights to improve learning outcomes. UNESCO's partnerships with AI initiatives also aim to expand education access in underprivileged regions.
- **Climate (SDG 13):** AI models predict climate patterns, aiding in disaster preparedness and resource management. By analyzing vast datasets, AI supports efforts to mitigate and adapt to climate change impacts. Microsoft's AI for Earth program has funded over 700 projects globally, tackling issues like deforestation and water conservation through AI-driven insights.

These applications underscore AI's potential to drive significant progress toward achieving global sustainability goals, offering hope for a more efficient and equitable future.

The Energy Cost of AI

While AI offers transformative solutions, its energy footprint is substantial. Training and running AI models, particularly large-scale deep learning systems, require enormous computational power. Here are some key statistics that highlight the energy demands of AI:

- **Training Large Models:** Training a single large AI model, such as OpenAI's GPT-3, can consume up to 1,287 megawatt-hours (MWh) of electricity, equivalent to the annual energy consumption of 120 average U.S. households. This process also emits approximately 626 metric tons of CO_2, comparable to the lifetime emissions of 5 cars or equivalent to the carbon footprint of multiple transatlantic flights.

- **Data Center Energy Use:** Data centers, which power AI systems, account for about 2% of global electricity consumption for approximately 460 terawatt-hours (TWh) of electricity annually. By 2028, global data center electricity consumption is expected to more than double, reaching 857 TWh, with a compound annual growth rate of 19.5% from 2023 to 2028. In the US alone, projections indicate that. data centers will consume approximately 292 TWh of electricity by 2026, representing about 6.5% of total U.S. power demand.

- **Inference Costs:** While training AI models is energy-intensive, the ongoing energy use for inference (running the models) is also significant. For example, deploying GPT-3 for widespread use could require thousands of GPUs running 24/7, consuming energy on par with small cities.

- **E-Waste and Hardware:** The hardware required for AI, such as GPUs and TPUs, has a significant environmental impact. The production of these components involves mining rare earth metals, which generates 1.4 tons of radioactive waste and 200 cubic meters of acidic wastewater per kilogram of material. Manufacturing a single NVIDIA A100 GPU emits around 1,000 kilograms of CO_2. The rapid pace of AI advancements leads to frequent hardware upgrades, creating massive e-waste. In 2019, the world generated 53.6 million metric tons of e-waste (with only 17.4% of e-waste recycled), projected to hit 74.7 million metric tons by 2030.

- **Cooling Costs:** Data centers running AI systems require extensive cooling to prevent overheating, which adds to their energy consumption. Cooling can account for up to 40% of a data center's total energy use. For example, a large data center can consume 20-50 megawatts (MW) of power, with a significant portion dedicated to cooling systems. This energy demand is equivalent to powering 20,000-50,000 homes in USA.

The Paradox: Balancing Benefits and Costs

The central question is whether the benefits of AI in combating climate change outweigh its energy costs. To address this dilemma, the focus must shift towards developing energy-efficient AI systems and adopting sustainable practices within the tech ecosystem. Innovations such as green data centers powered by renewable energy, more efficient algorithms, and hardware optimization are already making strides in this direction. Additionally, industry leaders and policymakers must work collaboratively to establish regulations and incentives that prioritize energy-efficient AI development, ensuring that technological progress does not come at the expense of environmental health. Key factors for consideration:

Renewable Energy Integration: If AI systems are powered by renewable energy, their environmental impact can be significantly reduced. Companies like Google, Microsoft and Amazon are already committing to 100% renewable energy for their data centers to become carbon-negative by 2030. Companies are as well investing in microgrids and on-site renewable energy generation to ensure a stable power supply by deploying solar-powered microgrids at some of its data centers, reducing reliance on the main grid. However, building renewable energy infrastructure, such as solar farms and wind turbines, requires significant upfront investment. For example, constructing a 100 MW solar farm can cost 100-150 million USD, depending on location and technology. Another important aspect to use AI driving efficiency in energy use across industries, potentially offsetting its own carbon footprint. For example, AI-optimized logistics and supply chains could reduce global emissions by up to 10%. AI-powered energy management systems can reduce energy waste by 10-20% in power grids. Also, AI-optimized logistics and route planning could reduce global transportation emissions by up to 10%, equivalent to more than 1.5 gigatons of CO_2 annually

Innovation in AI Design: Researchers are developing more energy-efficient AI algorithms and hardware. Techniques like model pruning, quantization, and federated learning can reduce the computational load of AI systems by up to 90% less energy without sacrificing performance. On the hardware manufacturing front, companies like NVIDIA, Google, and Intel are developing specialized hardware, such as Tensor Processing Units (TPUs) and Graphics Processing Units (GPUs), optimized for AI workloads. These chips are designed to perform AI tasks more efficiently, reducing energy consumption by up to 10x compared to general-purpose processors. Another important aspect is to consider Edge Computing. By processing data closer to the source (e.g., on IoT devices), edge computing reduces the need for energy-intensive data transmission to centralized servers. This approach can lower energy use by **20-30%** for AI applications like real-time video analysis.

Policy and Regulation: Governments, policy makers and industry leaders must establish guidelines to ensure sustainable AI development. This includes setting energy efficiency standards for data centers, incentivizing green AI research, and promoting transparency in AI's environmental impact. Strong policy frameworks are essential to ensure AI's sustainability. For example, The European Union AI Act, includes provisions for energy efficiency and environmental impact, such as Transparency Requirements, Sustainability Standards, Lifecycle Assessment. The EU estimates that these measures could reduce the carbon footprint of AI systems in Europe by up to 20% by 2030. In the United States, the Department of Energy (DOE) has launched the Energy-Efficient AI Initiative to promote sustainable AI development. Key components include: funding for research, public-private partnerships, and benchmarking tools. The DOE estimates that these efforts could reduce the energy consumption of AI systems in the U.S. by 30% by 2030.

Charting a Sustainable Future for AI

To ensure AI's contributions to sustainability are not undermined by its energy footprint, stakeholders across the ecosystem must take collective action. Researchers should focus on creating algorithms and hardware optimized for energy efficiency. Businesses should adopt sustainable AI deployment strategies, such as leveraging renewable energy-powered data centers and recycling old hardware.

Governments and policy makers play a pivotal role in this transition by enacting policies and providing infrastructure support for green technology. Furthermore, transparency in reporting AI's energy usage and its environmental impact is critical for accountability and improvement.

A multi-pronged approach shall consider:

- **Invest in Green AI:** Prioritize research into energy-efficient AI models and hardware. Governments and private sectors should fund initiatives that focus on reducing the carbon footprint of AI systems.

- **Adopt Renewable Energy:** Transitioning AI infrastructure to renewable energy sources is critical. Tech companies must lead by example, committing to carbon-neutral or carbon-negative operations.

- **Promote Responsible AI Use:** Encourage the development of AI applications that directly address sustainability challenges, such as climate modeling, energy optimization, and circular economy solutions.

- **Measure and Report:** Establish standardized metrics for measuring the environmental impact of AI systems. Transparency will drive accountability and innovation.
- **Public Awareness:** Educate stakeholders about the energy costs of AI and the importance of sustainable practices. This will foster a culture of responsibility among developers, businesses, and consumers.

AI's dual role as both a driver of sustainability and a significant energy consumer presents a complex challenge that requires innovative solutions and collaborative efforts. By investing in energy-efficient technologies, fostering partnerships, and implementing forward-thinking policies, we can ensure AI remains a powerful force for good.

Looking forward, emerging technologies like quantum computing hold the promise of radically reducing the energy footprint of AI systems. Additionally, developing standardized global frameworks for energy reporting and sustainability in AI deployment will be critical to maintaining transparency and accountability.

Public-private collaborations must also scale efforts to create energy-efficient infrastructures, particularly in developing nations where energy resources are limited. Moreover, expanding public awareness about the environmental impact of AI and fostering education around sustainable practices will be instrumental in creating a culture of responsibility

The key lies in striking the right balance between advancing innovation and managing its impact, enabling AI to truly deliver on its promise of a sustainable future. With collective efforts, we can harness AI's transformative potential while safeguarding the planet for generations to come.

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Before joining Twitter, George was the head of Public Policy for SAMENA Telecom Council, an ICT Industry Council based in the UAE, where he was in responsible of setting up, executing the council's policy plan and business strategies and shaping the ICT industry growth.

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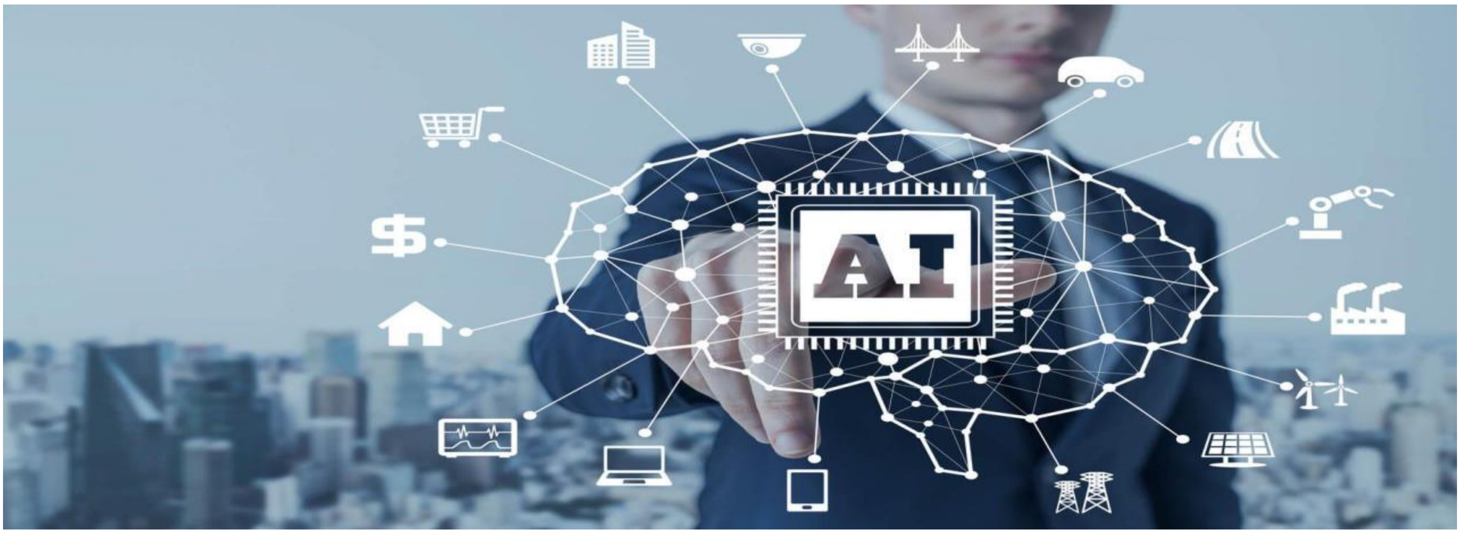

"THE NOT-SO-SIMPLE MACROECONOMICS OF AI" Why the Blind Spot in Daron Acemoglu's Framework Are Holding Us Back

BY DR. AHMED SHALABY MD, PHD, HEART SURGEON AND SUSTAINABLE AI CONSULTANT

The AI Shockwave: A World Unprepared for the Future

The rapid rise of artificial intelligence (AI) has hit the world like a thunderclap—a sudden, jarring force that has left us all scrambling to make sense of what's happening. It's as if we've been thrust into a new era overnight, one where machines can understand, learn, and perform tasks with a precision that was once the stuff of science fiction. Just a few years ago, the idea of AI writing essays, diagnosing diseases, or creating art seemed like a distant dream. Now, it's here, and the reality of what's unfolding is still sinking in.

The global stage wasn't ready for this. Governments, businesses, and even the creators of these technologies are caught in a state of bewilderment, struggling to comprehend the true magnitude of what has been unleashed. AI is evolving at lightning speed, and with each leap forward, the gap between what we understand and what we need to understand grows wider. This isn't just a technological shift—it's a seismic event that's reshaping the very fabric of our societies, economies, and daily lives.

Across the board, we're witnessing a frantic race to adapt. The private sector is rushing to integrate AI into industries, from healthcare to finance to entertainment. Governments are scrambling to draft regulations, trying to anticipate risks before they spiral out of control. Even the investors and developers behind these technologies are grappling with the implications of their creations, unsure of where this journey will ultimately lead.

The question we face now isn't whether AI will revolutionize our world—it's how we can reinvent our systems to coexist with this powerful new force. But here's the catch: our ability to see the future clearly is blurred by a critical blind spot. We're trying to navigate this new reality using old maps, frameworks, and ways of thinking that simply don't account for the complexity and speed of AI's evolution.

This blind spot isn't just a minor oversight—it's a fundamental flaw in how we approach the AI revolution. To truly understand its impact, we need to confront this blind spot head-on. And the best way to do that is through a concrete case study, one that reveals the limitations of our current thinking and points the way toward a more adaptive, resilient future.

Case Study: The Macroeconomic Blind Spot in Daron Acemoglu's "The Simple Macroeconomics of AI"

Daron Acemoglu, an Institute Professor at MIT and a leading voice in economics, is no stranger to groundbreaking ideas. In 2024, he was awarded the Nobel Prize in Economics, shared with others, for his influential contributions to understanding how technology and innovation shape economic prosperity. His seminal works, such as Why Nations Fail and Power and Progress, have redefined our understanding of the interplay between technology, institutions, and economic growth.

In 2024, Acemoglu turned his attention to artificial intelligence, publishing a working paper titled "The Simple Macroeconomics of AI." Shared through the National Bureau of Economic Research (NBER), the paper sparked widespread debate—not only for its insights but also for what it revealed about the limitations of traditional economic thinking in the age of AI.

Acemoglu's central argument is that AI has yet to deliver the disruptive impact on productivity growth that many expect. Using a well-established economic framework, he estimates AI's potential effects over the next decade and concludes that its contribution to productivity and GDP growth may be more modest than commonly believed. He suggests that unlocking AI's full potential will require a fundamental reorientation of the industry itself—specifically, a shift away from general-purpose AI models (like those capable of writing Shakespearean sonnets) toward tools that provide reliable, actionable information for specific professions, such as educators, healthcare workers, and tradespeople.

While Acemoglu's analysis is thoughtful and nuanced, it exposes a critical blind spot in macroeconomic thinking "the failure to use AI itself to analyze AI's impact."

The Blind Spot: Why Traditional Models Fall Short

Acemoglu's framework, though rigorous, relies on traditional economic models that are inherently static. These models are built on historical data and broad assumptions, making them ill-suited to capture the dynamic, non-linear nature of AI-driven economies. For example, Acemoglu's analysis assumes a linear progression of AI's impact, but the reality is far more unpredictable. By mid-2024, just months after his paper was announced, generative AI tools like ChatGPT had already transformed industries like customer service, healthcare, and content creation—shifts that traditional models struggle to anticipate.

What Acemoglu Missed: The Broader Implications of AI

Imagine a framework that integrates real-time job market data, AI-generated task classifications, and granular sector-specific modeling. Such an approach would not only enhance economic research but also demonstrate how AI can be a tool for understanding itself.

Acemoglu's decision not to incorporate AI-driven models, he missed the possibility to have automated framework, tested AI's impact on productivity in real time, and demonstrated how these technologies can enhance economic research. This practical application would have offered a real-world demonstration of AI's capabilities—not just in theory, but in practice. For example:

- **Data**: Instead of relying on historical data and expert classifications, an AI-driven approach could use real-time job market data and web scraping to capture emerging trends.
- **Task Classification**: Rather than manually categorizing tasks as "easy" or "hard," AI could dynamically classify tasks using natural language processing (NLP) and unsupervised learning.
- **Cognitive and Societal Risks**: The rise of AI-driven tools has led to digital addiction, declining critical thinking skills, and mental health issues, particularly among younger generations. These cognitive hazards could undermine long-term economic growth by eroding the workforce's ability to adapt and innovate.
- **Microeconomic Realities**: AI adoption is uneven, with early adopters and specific industries reaping disproportionate benefits. This dynamic exacerbates inequality and reshapes the nature of work itself, often at a pace that traditional economic models cannot capture.
- **Non-Linear Dynamics**: In today's digital economy, supply and demand are shaped by rapidly changing, non-linear factors. Early AI adopters benefit disproportionately, while others struggle to keep pace, widening the gap between those who harness AI's potential and those who are left behind.

The Bigger Picture: Rethinking Economics for the AI Age

Acemoglu's work highlights a broader issue: the need for economic thinking to evolve alongside technology. The blind spot in his analysis isn't just a flaw in the framework—it's a symptom of a larger problem. Traditional economic models, built for a slower, more predictable world, are struggling to keep up with the pace of AI-driven change.

To truly understand AI's impact, we need to embrace a two-sided adaptation: **both industries and economic thinking must evolve.** This means moving beyond static models and embracing dynamic, AI-driven frameworks that can capture the complexities of modern economies. It also means addressing the broader societal and cognitive risks posed by AI, ensuring that its benefits are shared equitably and its challenges are met with resilience.

Beyond Trust and Economics: The Blind Spot in AI Governance—Cognitive Hazards and the Talent Revolution

When it comes to regulating AI, the conversation often revolves around two main drivers: **security** and **economic gain**. While these are undeniably important, there's a glaring blind spot in the discussion: **cognitive hazards**. The rise of AI-driven tools has introduced a new set of risks, particularly for younger generations. Digital addiction, declining critical thinking skills, and mental health issues are becoming increasingly prevalent. These aren't just personal struggles—they're societal challenges with far-reaching economic implications. If unaddressed, they risk eroding the cognitive capabilities of an entire generation, undermining their ability to participate in the workforce and contribute to society.

Yet, these risks remain dangerously underexplored in the current regulatory landscape. The focus is too often on fitting AI into existing structures, rather than asking whether those structures are still relevant. What if the systems

we're trying to regulate are themselves outdated? Instead of forcing AI to conform to old frameworks, we need to rethink and reinvent our governance models to accommodate the new realities AI is creating.

Clearing the Blind Spots: New Economic Realities Beyond Labor Markets

The AI revolution demands a radical rethinking of how we structure our economies. The traditional concept of a **"labor market"** is no longer sufficient. In fact, the word **"labor"** itself is part of the problem—it conjures images of repetitive, manual tasks, precisely the kind of work AI is increasingly capable of handling.

What if we stopped thinking of humans as **"labor"** and started seeing them as **talent**? This shift in perspective would fundamentally change how we design markets and economies. In this new paradigm, AI takes over routine tasks, freeing humans to focus on what makes us uniquely human: creativity, innovation, social skills, and collaboration.

Imagine a world where schools no longer prepare students for jobs that machines can do, but instead nurture their talents as individuals. Education becomes about developing creativity, teamwork, and self-learning, with teachers acting as coaches guiding students to become well-rounded, self-driven contributors. The **"talent market"** replaces the labor market, becoming a dynamic space where time, data, ideas, and interactions hold tangible value.

A Vision for the Future: The Digital Sustainable Growth Model (DSGM)

The **Digital Sustainable Growth Model (DSGM)**, developed over 15 years of research at the **Human Information Technology Laboratory**, offers a bold vision for how societies can adapt to the age of AI. Inspired by the **biological intelligence** of human systems, the DSGM views society as a highly adaptive organism that thrives on both centralized coordination and decentralized autonomy as efficient as a living body.

The Biological Analogy: Society as a Living System

Consider the human body, a marvel of biological engineering. It consists of approximately **37.2 trillion cells**, each specialized for specific functions—muscle contraction, oxygen transport, immune defense, and more. These cells work in harmony, constantly responding to internal and external changes through precise feedback loops. This balance between centralized control (e.g., the brain) and decentralized autonomy (e.g., individual cells) ensures the body's overall health and performance.

The DSGM applies this insight to socio-economic systems. Just as the cells of the human body work toward the well-being of the organism, our societies should strive for **socio-economic performance indicators** that reflect both individual and collective well-being. By creating a governance model that combines centralized coordination with decentralized autonomy, we can build a highly adaptive system capable of responding to rapid technological change with precision and efficiency.

Reimagining the Economy as a Platform

The DSGM shifts the focus from traditional labor markets to **talent markets**, where individuals are valued for their unique abilities and potential. AI handles routine tasks, freeing humans to focus on creativity, innovation, and social

collaboration. Education becomes a lifelong journey of personal development, with schools nurturing talent rather than preparing students for obsolete jobs.

At the heart of this vision is **Growth Media**, a digital platform that uses data and intelligence to foster growth for individuals, companies, and nations. This platform empowers citizens to act as entrepreneurs, innovators, and investors throughout their lives, creating a dynamic ecosystem where time, data, ideas, and interactions hold tangible value.

Transforming Governance and Public Services

The DSGM also reimagines governance to meet the challenges of the AI age. For example, it proposes leveraging AI to deliver **personalized care** in education and healthcare at scale, reducing costs while creating new opportunities for collaboration between public institutions and the private sector. Traditionally seen as cost centers, these sectors can become **income-generating entities** under the DSGM, driving innovation and addressing pressing issues like rising global debt.

The model even proposes a **global platform** aligned with the UN's Sustainable Development Goals (SDGs), fostering international collaboration to close the global debt gap and promote sustainable growth.

Closing Remarks:

The age of **Artificial Humanity** is upon us. How we choose to shape the future in the face of AI's rise will determine the fate of governance, economy, and society for generations to come. The **Digital Sustainable Growth Model (DSGM)** offers a roadmap for navigating this complex landscape, ensuring we harness the potential of AI and emerging technologies—like **6G**, **quantum computing**, and **Artificial General Intelligence (AGI)**—while mitigating their risks.

But the DSGM is more than a model—it's a **call to action**. It challenges us to rethink the very fabric of our societies, economies, and governance systems. By embracing AI as a partner and reinventing our systems to reflect the realities of the digital age, we can create a future that is not only resilient but also thriving.

The age of AI is here, and with it comes both immense opportunity and profound challenges. The question is not whether we can adapt, but whether we have the courage to reinvent ourselves for this new era.

For further readings

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Dr. Ahmed Shalaby, MD, PhD is a heart surgeon and Sustainable AI consultant with over 26 years of experience bridging artificial intelligence, sustainable growth, and human-centered technology. As the founder of the Human Information Technology Laboratory (HIT Lab), he developed the Digital Sustainable Growth Model (DSGM), a framework that sets global standards for ethical AI and sustainable economic practice.

Key Achievements and Contributions

1. **Shalaby's Classification for Digital Hazards**: Dr. Shalaby developed a novel classification framework for digital and cognitive AI hazards, aiming to comprehensively categorize risks such as digital addiction, cognitive erosion, and mental health issues, particularly among younger generations. This framework is a critical step toward establishing automated safety standards for protecting human minds in the digital age.

2. **Digital Sustainable Growth Model (DSGM)**: The DSGM is a holistic framework that reimagines socio-economic systems by integrating AI-driven solutions for sustainable growth. It emphasizes the transformation of data into value, fostering innovation, and addressing global challenges like rising debt and inequality.

3. **Growth Media**: As part of the DSGM, Dr. Shalaby introduced the concept of **Growth Media**, a digital platform designed to empower individuals, companies, and nations by leveraging data and intelligence to drive growth and innovation.

4. **Publications and Research**: Dr. Shalaby has authored numerous influential works, including *"WHY: In the Digital Millennium Intelligence is Your Biggest WHY"* and *"Sustain Your Ability,"* which distill years of research into actionable insights for personal and societal growth

5. **Global Impact**: Through his work at the HIT Lab, Dr. Shalaby has fostered international cooperation, advocating for ethical AI deployment and sustainable economic practices. His research has been instrumental in shaping policies and frameworks that address the challenges of the digital age.

DEFENCE RADIO SPECTRUM USE - OVERVIEW OF KEY ISSUES

BY SELÇUK KIRTAY AND TIM MILLER

Introduction

The use of spectrum by defence is extensive and this is increasingly taking place in a congested and contested radio environment. The radio spectrum enables many defence applications across land, sea, air and space domains to fulfil a significant number of functions including command and control; intelligence gathering; position, navigation and timing; weapon guidance; data transmission; and electronic attack. These applications often operate in close proximity both temporary and spatially with overlapping spectral characteristics. In addition, the use of spectrum is constrained by laws, treaties, and regulations that govern access and drive technology availability. This paper discusses some of the key issues associated with current and future use of radio spectrum by defence and security applications.

Key issues

There are several key issues to consider associated with frequency bands where defence systems are deployed. These include

- migration of legacy assignments,
- increasing spectrum utilisation,
- addressing congestion, and
- enabling developing technologies.'

Migration of legacy assignments

When it comes to spectrum use compliance with NFP is essential. However, there may be defence systems, which could be part of critical infrastructure, not aligned with NFP allocations. These will have to be migrated to appropriate bands without compromising critical services supported. A typical example is the operation of defence fixed links in bands with no fixed service allocation. Migration can place at the end of equipment life; at the licence/authorisation expiry; or at a time set by the national regulator. In recent years, fixed links are migrated to higher bands to enable other services, e.g. IMT. Defence stakeholders choose to migrate to upper bands where more efficient technology is on offer. The use of spectrum fees also may act as an incentive to migrate. The main challenges are identifying new bands to migrate and ensure that equipment is available to fulfil service requirements.

Increasing spectrum utilisation

It is not unusual to see a few defence assignments occupying a considerable amount of spectrum. Radars are a good example given traditional high power deployments associated with these systems. If the assignment is based on a countrywide authorisation this almost makes it impossible to consider any other use in the band. However, recent technology advancements including significantly reduced transmitted power necessary to achieve improved range and target discrimination performance coupled with beam forming, improved antenna and receiver designs have improved spectrum efficiency and potential for coexistence. Further improvements such as passive radars (capable of exploiting transmissions from communications, broadcast or navigation systems), diverse waveforms (leading to optimisation of waveforms based on mission requirements), and cognitive approaches (enabling autonomous decision making) will make radars more spectrum friendly in terms of coexistence with other radio systems.

Addressing congestion

In sub-GHz bands, narrowband technologies enable widespread civil and defence deployments which may result in a congestion problem. To address this, there are several replanning/refarming approaches that can be considered: the use of more spectrally efficient digital equipment, incorporation of narrowband channels, and more spectrum sharing on the same channel for systems having low spectrum occupancy. However, it is worth noting that changing the channel plans of narrowband widespread systems is a major operation, and cost and frequency coordination with neighbouring countries using different channel plans need to be considered. Furthermore, requirements including high power emission, frequency hopping and security aspects may prohibit the use of developing technologies by defence systems as suitable replacement of currently deployed technologies. The development of critical networks for exclusive defence use in certain sub-bands could be also considered to ease the current pressure on spectrum resources.

Enabling developing technologies

There are many defence technologies under development that are likely to raise demand for spectrum. It is difficult to categorise all of them, but the key areas of development include IMT, unmanned systems, space networks, sensors and radars. The adoption of developing technologies in any jurisdiction will depend on several factors including the demand and need of key stakeholders; availability of targeted frequency bands; impact on incumbent use in targeted frequency bands; and cost and availability of equipment. For example, recent years have seen a dramatic increase in the use of unmanned aerial vehicles (UAVs) and the band 5030 – 5091 MHz was identified to support command and control links associated with UAVs operating both visual line of sight and beyond visual line of sight. In the defence context, geographically unconstrained and mission critical UAV use may require exclusive frequency band allocation to cater for a wide range of possible deployment scenarios, e.g. swarms and autonomous systems for intelligence, surveillance, reconnaissance, and long-range weapons delivery.

Conclusion

Prioritisation of radio spectrum for defence and security agencies is a complex area where the balance needs to be struck by considering national and international needs. Incumbent and emerging defence technologies alongside national, regional and global political developments will affect the future use of radio spectrum by defence applications. Continuing and innovative developments are expected.

ABOUT THE AUTHOR

Selçuk Kırtay,

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Selçuk Kırtay is a Principal Consultant at Plum and has over 20 years of experience in radio spectrum management. Selçuk's core activities are wireless network technologies; spectrum licensing regimes; and design, modelling and analysis of terrestrial and satellite radio network deployment and coexistence scenarios.

Selçuk regularly develops deterministic / statistical analysis tools, incorporating a range of radio propagation models, used for investigating radio frequency sharing and coverage requirements as well as interference mitigation techniques. Much of his work aims to optimise the use of radio spectrum by deriving appropriate technical conditions including limits on in band and out-of-band transmission power levels, acceptable interference levels, guard bands, geographic separations and filtering requirements which can be adopted when defining licence conditions.

Selçuk has a depth of knowledge in spectrum authorisation and telecommunications service licensing regimes adopted in different parts of the world. He has drafted a range of regulatory instruments including regulations, guidelines and policies. Examples of Selçuk's work include coexistence studies involving mobile/fixed communications networks, air-to-ground radio networks, satellite constellations, telemetry systems, business radio networks, short range devices, passive services, radars and broadcasting systems; technology roadmaps for cognitive radio and public protection disaster relief networks; spectrum requirements for nationwide business radio networks; analysis of cross-border frequency sharing conditions; radio technologies developed for operation in licence-exempt bands; and satellite system filing preparation and coordination activities.

Selçuk has experience in using the CEPT interference analysis tool, SEAMCAT, and ITU-R terrestrial and space networks and related software. He is familiar with the EU framework programme for research and innovation (Horizon 2020). As part of projects undertaken, he regularly prepares and reviews technical submissions to ITU R/CEPT/ETSI technical study groups as well as consultations launched by national regulators. Selçuk also represents clients at national / international technical study groups.

Selçuk holds a BSc degree in Electronics and Telecommunications Engineering from Istanbul Technical University, an MSc in Telecommunications and Computer Engineering from University of Surrey and a PhD in Radiocommunications from University of Warwick. He is a Chartered Engineer and Member of the Institution of Engineering and Technology

Tim Miller,

Partner at Plum Consulting

TTim Miller is a Partner at Plum and specialises in the application of economic theory to telecommunications issues, with a particular focus on regulation, competition, and spectrum policy and strategy.
His advice has been used by operators to lobby for changes to regulation, and by governments and regulators to form regulatory policy and strategy.
Tim has developed models and analytical tools for operators, regulators and governments around the world to assess the value of spectrum and how it should be awarded. He has also provided advice on how spectrum may be used – from both a technical and regulatory perspective – in mobile and fixed networks.
His work considers the analysis of markets and company interactions, both in terms of their impact on spectrum awards and on egulation in general. He is adept at applying established regulations to emerging markets, particularly those in Africa, Latin America and the Middle East, but is keen to develop new regulatory thinking to reflect the changing nature of today's telecommunications markets, applied to markets worldwide.
He has applied game theory to market interactions to enable operators and regulators to understand likely outcomes of decisions, and how to mitigate against unwanted effects.
His work has also included mobile broadband regulation, the estimation of demand for data traffic, economic impact and cost-benefit analyses, the pricing of regulated services, broadcasting cost models, undersea cable disputes, mobile number portability, universal service cost calculations, and structural separation.
Tim Miller has an MSc in Economics from the University of Bristol, specialising in auction and game theory, and a BSc in Economics and Mathematics from the same institution.

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