Notes on the RSPG review report NOV 2024, RSPG24-030 FINAL, 13 NOV 2024

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The analysis here follows the structure of the RSPG 6G report :-

Contents of RSPG draft report

1 Executive summary (p2 of the report)

Unfortunately the RSPG report draft on spectrum for 6G has been based on the current somewhat arbitrary state of affairs, and is less value than it could be. This is not the fault of the RSPG, more that the state of development of the 6G research initiative is not yet well enough defined before further attempts at setting an authorisation strategy at an NRA level.

The basic principles of what 6G is in terms of its market and thus its key functional specification - and then its overall architecture - with its main technical attributes in functional terms, has yet to be evaluated. The research efforts so far are far from being mature enough. Thus, it is fairly impossible for the RSPG report to be very useful, due to the current inadequate basis for recommendations. Evidently the R&D situation so far should also be looking into replacing 5G.

In consequence, the 6G development reviewed here can cover only a limited survey of the potential changes and their probable advances and problems. Inevitably, the result is a quite restricted view, so any suggestions here are not yet consistent with a stable assessment of a new communications environment, which should offer an expected useful operational life of at least two decades.

The considerations here are thus based on an evaluation of an incomplete body of work with some six use cases, whose relevance may be challenged. Hence real coverage and capacity needs for the future demands of European society may be questionable. Working scenarios for 6G seem to be largely taken from ITU-R, using the ITU-R IMT-2030 framework. This has been presented by a set of academic and mobile industry supplier players and thus (so far) is limited to the supply side perspectives largely. Hence its thinking seems to pursue a fairly narrow update of the current 5G technology, rather than to correct its mistakes, and, of course bring in new useful capabilities, which it seems to lack. The emphasis should be on the useful. Instead, it seems to try to extend 5G NR NSA capabilities in some fairly mundane expected directions (especially ‘the metaverse’ – obsolete since 1989) following the supply side’s need to churn the mobile software and equipment market.

The report states that the RSPG has taken input from a range of active stakeholders, such as research institutes, manufacturers, mobile network operators (MNOs) and satellite operators. on the following topics:-

 A l l r i g h t s r e s e r v e d

- Future rollouts of 5G to 2030, with its use cases for future spectrum needs,
- Readiness for launch of 6G in 2030 for a mass market in mobile services and equipment, with the role of private networks based on 6G, The role of Non-Terrestrial Networks (NTN)
- Spectrum sharing and use of licence-exempt (LE) spectrum
- Device to device (D2D), or relay working, but without any authorisation models

Areas that also need to be reinforced include key problem areas, not yet well covered:-
- Sustainability
- Security – this has many diverse facets today as social impacts expand and NRAs take on new responsibilities[1] whereby network shutdown is an option (as in the UK's OSA, 2025)
- Financial evaluation of the technology in terms of capex, opex and rate of return on investments (RRoI) with some idea of the business case - to inform NRAs of the likelihood of take-up of this technology

The text does include ONE quite sensible basic consideration:-
- To achieve reliable nationwide-area coverage *low-band spectrum (below 1 GHz) is recognised as essential*. This is probably fairly useful as a first step based on today's thinking about signal propagation. Also that this can be supplemented in the future by non-terrestrial networks (NTN) - which is a far more interesting direction.

Higher frequency bands in sub-7 GHz are considered necessary, including the upper 6 GHz band, as well as new bands in the 7-15 GHz range, millimetric and of course the terahertz fiasco. Whether this will be successful is uncertain without breaking user experience, sustainability and cost limits.

Missing – key areas to add for NRAs

1 Network power demands and emissions – somewhat as expected from a supplier and industry standards led initiative, as a technocentric project, with no user input requirements – it contains (somewhat surprisingly) - no analysis of power demands against frequency and cell density implied. For instance for certain higher frequencies, only the 2x - 20x high power of MIMO narrow beam directional antenna can ensure communication to a handset and perhaps also for the return path to the cell site transceiver. Setting spectrum bands to minimise this power for longer distances of coverage with measured *indoor* mean signal strength should be considered.
2 The above leads to the analysis of the costs of using some the upper bands considered in terms of capex across geographic rollout – especially bands included as 6G target bands (7-20 GHz)
3 Radiation emissions in public spaces and private residences are a spectrum dependent factor that is not considered (and perhaps should be mandatory in that ICNERP - International Committee on Non-Ionising Radiation Protection- investigations are inevitable).

In summary
There are a number of key points missing. Some of which might be viewed as rather unfortunate as they include:-

No consideration of the financial business case – current pricing for mobile is far too high, partly due to two factors – the access limits given by auctions based on allocation of frequencies and secondly the resultant lack of free market competition that follows.

[1] Regulatory Networking Meeting (RNM, NBTC, ASEAN with Japan, South Korea, Australia, Telecoms conference Phuket, 6-8 Dec 2023, Thailand) *The Future shape of Telecommunications Regulations and Regulators*, Keynote pres., on new regulatory models and challenges for NRAs supervising the telecommunications, media and platform technology sectors, SCF Associates Ltd, 2023.

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This does not seem to enter design consideration for 6G here. Thus there should be careful consideration of licence exempt and shared spectrum far more. An analysis for the market for 6G should define its architecture and core features and thus its intended cost base and if it meets target market needs. Without those business case parameters speculating on its spectrum is an academic exercise, perhaps without value.

The report's summary reflects the current form and thinking on spectrum use – this follows the business model of the mobile retail industry structure today, of a few dominant players in each MS, assigned spectrum at auction. However, there could the problems, as seen with 5G, that relying on the premise that if you build 'it' ('6G') they (the public - and thus the MNOs) will come. But they probably will not - as nobody – especially the MNOs understand what is 5G commercially, and especially technically. So far, the same lack of clarity exists around 6G except that it is even less well defined for consumers and operators than 5G, as might be expected for a paper exercises so far. So this study again risks bowing to a mobile system design that nobody wants (as 5G did when millimetric bands, of 25-30 GHz were touted as the prime band without considering range or indoor use - especially with a pico-watt signal strength thru-wall).

Hence, in some ways, the 6G outline here recalls the state of 3G UMTS back in 2000 - 2005 – a failure before rollout - as it was a system for video applications without the packet structure, packet rate, overall mass throughput or the video resolution and quality in the handset that LTE-A (Pro) ultimately provides at fairly low cost.

On some other points this draft is *possibly* correct to propose spectrum sharing between MNOs and local/private networks. That needs to be incorporated into 6G spectrum discussions from the beginning (Ch8) of the technology development phase and not be a restriction imposed afterwards. But the main target is sharing between MNOs – so that they might have each spectrum channel access on a needs basis, with local session-only coverage. Effectively there is no analysis of how 6G could use spectrum far more wisely and judiciously – as it requires rethinking block allocations and lifetime assignments, innovatively. Taking that initiative – to be constructively and creatively critical of the current range of what is being presented from a scattering of early and fairly poor technological and academic research - seems to be missing from this analysis. That makes it of less use to pragmatic regulators.

The paper's summary does conclude that the RSPG will consider spectrum needs on the basis of the 6 ITU use-cases but these are based on ITU-R's IMT for 6G. Although that might be one place to start, it is constrained by the ITU and its own 5G IMT weaknesses, which generally are on the supply side, not the demand side, driven. Thus this is the basis of the RSPG proposals for a 6G roadmap that includes user industry applications ('verticals'). One would hope that a UN body might be more conscious of the user population but those who have worked with it have seen its internal capabilities and scope for neutral thinking creatively on technical subjects.

Generally what we see here in the draft is somewhat tangled in its thinking:-

- what are the real aims of this analysis is unclear– to provide useful mobile communications systems that will become viable businesses, and/***or,*** to try and build industrial control systems, using mobile mass communications (and when there are better and cheaper dedicated communications systems)

- taking some early decisions, that may be regretted at leisure - eg note that deciding on 200MHz per operator at this stage could be a 200MHz slice too far.

More positively the paper does realise that spectrum sharing may be the way forward although it does not cover new apportionment methods as alternatives to first *Allocation of function* and

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then *Assignment to operator.* But it mentions inter-service sharing, presumably across the functional allocations of spectrum bands. It partially realises that unlicensed spectrum could be considered as more important in the future.

In summary

The draft report is perhaps somewhat biased in its findings and analysis, in that it is heavily directed towards the perspective of another 5G mobile rollout being continued with some fairly minor updates as 6G. It results in a minimal upgrade to the 5G failure -really a kind of ***"5.2G"*** because the research sources it uses (ITU, the suppliers, etc) are noted for not thinking beyond the supply side's next market-churning product cycle (see European Parliament paper, 2018[2], "Leadership in 5G" which discusses the basic industrial policy problems of the mobile technology market).

Essentially**,** the 6G model that RSPG is describing here is an incremental form of 5G – not a new generation, apart from potential further integration with LEOs and an 'interesting' excursion into THz (presumably only for in-space communications) although the major effort and advances by the USA leaders in long distance, in-space networks is in laser connectivity, across free space (for broadband multichannel) optical communications networks (FSOCNs).
However, if the RSPG's remit is just to follow the proposals set out by the supply side, as accepted, unfortunately, by the statutory bodies who recommend this work, such as the ITU, then this may be a suitable document.

Alternatively, what may be far better, would be *a position paper* from the RSPG that acknowledges the state of the art given by the supply side currently, but noting its failures to offer anything new, useful and contributing to the macroeconomic development of the EU, and awaiting a more perfectly formed specification.

The review may then even suggest just how spectrum could be used far more effectively in the future. However, this may not be possible if the RSPG sees its role as follower, not a contributor to the debate on optimal use of the spectrum. Note that this task would be a responsibility of the collective of spectrum regulators at EU level while reflecting on Member State's concerns for promotion of optimising the economic and social benefits of the EU spectrum assets.

[In addition- although this is a draft - a *list of contents* would aid reviewers]

Analysis by section follows:-

2. 5G and lessons learnt (p4 in the report)

It is very unclear if the lessons learnt from the 5G experience are of much help to a really new generation (called here 6G) except that if this "6G" is a fairly simple upgrade of 5G, to perhaps '5.2G' then of course it may be highly relevant. Learning from the mistakes is the valuable part.

However, the underpinnings of 5G radio technology are particularly complex technically and expensive, and these intricacies are still far from being resolved – for instance the nonlinear emissions feedback behaviour between handsets and base station transceiver (BTS) with beamforming. The basic 5G operating premise is to use many more small cells, or SAWAPs in the EECC (2018) nomenclature, for better Internet packet transmission at higher frequencies with wider bandwidth for faster data rates. This is a limited goal that has not been completely met, especially on uplink data speeds. Its aim has been to improve on earlier generations of

[2] European Parliament, Directorate General for Internal Policies, Policy Department A: Economic And Scientific Policy European Leadership in 5G (S. Forge, SCF Associates Ltd, contract holder Camford Associates. C. Blackman

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mobile cellular radio, which may be viewed as limited and only partially successful attempts at broadband coverage nationally by MS. However, broadband downlink speeds of LTE-A Pro, the currently dominant mobile generation provide adequate service and that limits the new capex necessary from the MNOs.

Some of the key points noted in this section are:-

- Millimetric bands have little practical use for public wide are networks except in very small coverage areas and Wi-Fi is quire adequate and is much cheaper and more reliable

- Moreover, such bands may require significantly higher power for coverage over areas larger than a single building, and will require expensive antenna equipment, especially if beamforming is required.

- The whole question of sustainability of 5G in terms of power demands is unclear in this draft – it could be expected to be present firstly in lessons learnt. Note that when the three MNOs in China were at the stage of 5G rollout that the EU has now, the operators threatened to halt rollout unless the government repaid the electricity costs in full.

- The planning of widespread 5G networks may be severely constrained by the limits on maximum EMF levels established in a wide set of regulations. The goal of this work should be to shed light on EMF-aware 5G network planning, and in particular on the problem of site selection for 5G BS equipment that abides by the downlink EMF limits. To this end, we should have an analysis to present the current state of the art in EMF-aware mobile networking, and overview the current exposure limits and how the EMF constraints may impact 5G planning.

Hence the impracticality of using the millimetric bands (20-40GHz).is fairly clear. One lesson from the 5G experience is that a service that is costly, has low range, with poor quality signals does not sell. The customer's user experience is a questioning of why it exists at all – what advantage does it bring the customer?

Whether coverage really equals take-up by the public for a technology that is so expensive, requires such high basestation density (especially in the centimetric (7-20GHz) and millimetric (20- 40 GHz) and offers poor indoor performance is open to question. Overall the technology of 6G, as represented here, is little different to 5G and 5G has a somewhat difficult set of goals, and history. It is a technology that:-
- The telecoms network supply chain wanted – not the public, or the MNOs- so the suppliers could have a new model to sell – ie to churn the market – in a pure supply-side push
- The MNOs have been reluctant to take it - as there is no good reason for a customer to take it. Moreover LTE-A Pro has been sufficiently expensive to install such that full pay back to the MNO may be beyond 2030.
- The public sees 5G as expensive and as not offering tangible reasons to buy it.
- The suggested emphasis on 'Terahertz' communications seems valid for non-terrestrial communications, in space, although '6G' proponents seem to waver between 90 and 300 GHz as a terrestrial band (actually 0.09 – 0.3 THz).
- Addition of mobile satellite interfaces is an important development but hardly new to 6G, as so far defined (ITU-R, M.2514-010, 2022).

The model of spectrum sharing could be continued, wherever appropriate for the 6G market between different MNOs, their services and technologies, so dynamic distribution of spectrum bandwidth, with fluid allocations across MNOs could be possible.

The NSA model of using the LTE-A Pro Core network into the basestation sites could be reused for 6G if the basic operational model of 6G is really 5.2G – that is, it is just a minor upgrade to churn the market for the equipment suppliers. This is not what many hoped 6G could be – it is simply a repeat of the same mistakes – probably in a costlier framework.

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Although it could be seen as a retrograde step, mobile network intergenerational sharing could be possible, especially if 6G is just a fairly minor 5G update so the same spectrum bands could be used across the generations ('6G', LTE-A Pro and 5G, SA or NSA). It does require base stations able to handle multi-protocol systems. That gets complex with beamforming, unless the hardware and software are similar. If not, multiple antennae might be needed, especially for beamforming at different frequencies. Most attractive is traffic shaping, matching the capacity available for each mobile generation to its traffic demand to avoid saturation and dropped sessions. The net advantage is in real estate demands for BTS sites – which are reduced by reusing the same LTE-A/ 5G-NR sites, towers, ducts and possibly the same core network connectivity – although site bandwidth connectivity may have to increase. In some way this is attractive but it also has the major limitation of greatly restricting the advances that 6G could make over 5G and the LTE-A core network. It also tends to conserve 5G and all its problems which 6G should be about solving, as well as its core network protocols.

The other feature of a new shared approach to spectrum could be dynamic re-farming that allows the base station to dedicate capacity according to traffic loads, dynamically adjusting spectrum allocation between technologies. Although intra MNO sharing is an effective tool for a smooth migration from 4G to 5G, there are limitations to consider in its adoption, especially in low bands, impacting peak transfer and affecting the user experience. Today, this method allows LTE-A ('4G') to coexist with 5G, without discontinuation of the 'LTE-A service.

In theory this lessons learnt section should also cover sustainability but there is little here except for some accepted wisdom generally suitable for the 5G model of 6G:-

- Reuse of the 5G frequencies – 700 MHZ "Pioneer" - but spectrum block size may be too small (5- 10 MHz often used for LTE-A but wider bands may be needed for 5G).
- It is also well to note that to save large capex, then the 5G NSA model might be needed for 6G, especially if it is really a form of 5G (ie re-use LTE-A core network with 6G RAN - but what band for relay working (D2D") between devices is unclear)

Migration to 5G non standalone (NSA) to 5G standalone (with its own expensive core network and insecure levels of virtualisation for single-point-of-failure (SPOF) modes) has not been widely followed so far in the EU. MNOs are only reluctantly prepared to take on the high risk investment of a 5G core network because the RoI is quite uncertain.
The risk is so high that in some countries (eg the UK) MNO consolidation (from 4 to 3) is considered necessary to protect positive cashflows over the migration phase of 2 to 5 years, especially with current cost of borrowing (3-4% rising towards 6% expected in future years). Thus 6G might promote MNO pressures on administrations for a 3 to 2 operator market in each MS, unless the 6G engineering is aimed towards economics that are more profitable with rapid rates of RoI, and most importantly, the 6G technology – and its business model- is designed for enabling new market entrants, for high competition to restore value for money for the consumer. Moreover, following a path of leveraging current infrastructure of LTE-A Pro core and RAN, with shared base station sites, to reduce infrastructure duplication is an obvious model follow.

MNOs can then leapfrog 5G and go for a lower cost generation, with useful advanced features *However much of the promised (yet to be proven as scale) technological evolution is for 5G SA. Currently, there are still a significant number of European MNOs in an intermediate stage of 5G adoption, as they maintain the massive use of 5G NSA without a clear perspective for adopting 5G SA.*

The discussion on NSA to SA is a 5G problem that perhaps should NOT be expected in a 6G study, if 6G is truly a next generation. However as noted, really the technology reviewed here and in later chapters appears to resemble more of an attempt to repeat the recycling of UMTS with a *long term evolution* (LTE) but now for 5G NSA/SA, more than a usefully advanced complete replacement with new and desired features – simple, secure, low cost. These

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comments emphasise that the 6G presented here may be only a ***transition technology for 5G.*** It underscores the role seen for 6G as a "clean-up" release, just as LTE repaired the packet format and other problems of 3G UMTS, so coexistence is important**.** However, the expectation is that in the coming few years Europe will catch up with the other global regions. The latter may not happen as even Ericsson in some sources expects LTE-A to continue beyond 2030 and perhaps beyond 2035.

The satellite component of 5G is also proposed as the basis for 6G – in a way that is possibly sensible only if 6G strongly resembles the 5G model. However, reusing the 5G use cases may seem to be a step backwards – so this is not 6G - but 5.1G, or perhaps 5.2G. Still, there appears to be little appreciation that mobile handsets would possibly be directly connected to LEO satellites in outdoor situations for video streaming and voice/messaging (perhaps 20% of use) with 80% of use being indoor reception via a building (and perhaps with a thru-wall repeater being needed).

The discussion on mobile satellite services, MSS, (for broadband streaming) is useful, noting the need for public standards in the EU covering public standards for:-

- Convergence between MSS and mobile services.
- Direct device-to-device (D2D) satellite networks for terrestrial handsets and receivers.

One key question not reviewed is whether the dedicated industrial networks in the 2030's will be much cheaper to procure, install and operate in that timeframe (eg ZigBee and its many successors) – and will include licence-exempt technologies for updated versions of Wi-Fi, NFC, etc, as carriers for industrial protocols – such as Industrial Ethernet, EtherCAT, Gigabit Ethernet, etc. The extension of telecommunications protocols into control engineering roles is an unclear development. Certainly, from the experience of the EU RRS (reconfigurable radio systems) market for supervisory industrial control and data systems, mobile technology has not been considered as a serious contender. From surveys in Asia's rapidly industrialising economies, the low cost and higher speed of specialised industrial control technologies, based on LE public spectrum in standard spectrum bands is dominant and the entry of 5G (or 6G) technology from mobile markets is not considered.

This all implies 6G is a fairly minor extension of 5G – if so, there is **little call for new spectrum** as the functionality (and low take-up) will much the same, so that LTE will still actually carry the majority of users' traffic. LTE would then continue in a dominant role as the 'background' main mobile network. However LTE core may have an interfacing extension for at least three air interfaces (native LTE-A Pro, 5G NSA, 6G) and also and possibly satellite and D2D. That would make spectrum demands be led by the continuing role of LTE-A Pro and its updates. Prognostications of enormous expansion in spectrum demand could be misleading. Jam is always tomorrow.

Much of the 6G prognostications seem to be as likely as 5G being taken up (with 2% EU penetration in 2022 – OOKLA, 2022) and 5G upload performance in 2024 (OOKLA) is static at 19.90Mbps. Thus the reports endorsements deserve to be taken with some caution:

> *"The spectrum need for local and vertical use will still increase, which needs to be taken into account in future spectrum strategies, considering also relevant developments and timing of harmonisation in bands recommended for verticals".*

This needs to be treated with care. With advances in engineering, new generations should not mean more mobile spectrum - but less - or there is no advance. Therefore, one of the major improvements made by progress to 6G should be an end to the ceaseless demand for greater mobile spectrum. However, this is not yet the case here.

If 6G is a minor upgrade on 5G, with basically the same 5G model of slicing, virtualisation and concentrated SAWAP density, due to low range at high frequencies (26GHz) this would make

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projecting 6G demand based on 5G, with the lack of take-up, a difficult correlation to take as valid.

3 Early policy initiatives on 6G (p 10)

This is an area awaiting further developments in 6G research. Unfortunately, there is little real content perhaps due to a lack of clear indications of directions from 6G research initiatives so far – instead there is a general view, with the basis of discussion being that 6G should have its own unique and unshared frequency bands for its basestations and RAN but that this was difficult:-

> *"RSPG identified the limited new resources that could be made available to support the launch of 6G. For example, even if WRC 23 identified 6425-7125 MHz for IMT, the upper 6 GHz band is subject to another RSPG Opinion. Except for 7125-7250 MHz, the European position at WRC-23 was to oppose studying additional IMT".*

That is why the 700 MHz band recommendation, made initially, is so important for deployment with reduction in major capex and opex costs and with superior *indoor* signal strength. But in practical implementations it is quite a wide band - possibly up to 900 MHz and taken down to as far as 425 MHz even. More significantly it is therefore claimed by many other spectrum users - TV broadcasting with DTT, also mobile LTE-A, 5G NSA and SA and possibly even the remnants of UMTS and analogue GSM 2G in some EU MS, plus some private cellular networks at 450 MHz used by power utilities and also GSM-R for certain railways. Whether this is a request for ***unique bands for 6G only*** is unclear. What is clear is the similarity of current 5G variants to the spectrum being proposed for 6G, pointing to 6G as a 5G upgrade at a policy level as :-

"With 5G the early identification by the RSPG of the need for low frequency bands (coverage in 700 MHz), mid (capacity in 3.5 GHz) and high (pioneering and innovation in 26 GHz) bands for 5G proved to be the right recipe" [24].

This is a somewhat questionable conclusion, while 700MHz is obviously a safe choice, however the C-band and centimetric (7 - 20GHz) and in millimetric (23 - 29GHz) are contentious – a conclusion from working on network design and business models for 6 recent spectrum auctions, including 3 for 5G, and of the MNO financial returns over time, especially for these upper frequencies).

The declared intention to use Tera Hertz frequencies by some 6G projects (eg Ericsson Hexa-x) for 1Tbps bit rates needs a lot of development – with beam forming, and also avoidance of atmospheric losses, so analysis of power required is needed in the beam forming design, with radiation hazards research and avoidance. Naturally, it is unclear if the demand is there, unless the intention is to use THz only *in space* out of atmospheric absorption, as directional beams on-demand for trunk links between satellite-based switching systems. However this is rivalled by optic beams in space with higher capacity and possibly lower cost, are already being deployed although global peak traffic capacity levels and operational latencies are yet to be proved (eg Rivada – USA/RFA).

RSPG has identified some (limited) resources that could be made available to support the launch of 6G. For example, even if WRC 23 identified 6425-7125 MHz for IMT, the upper 6 GHz band is subject to another RSPG Opinion. Except for 7125-7250 MHz, the European position at WRC-23 was to oppose studying additional IMT identifications in frequency bands where IMT would have the potential to jeopardise strategic and important European spectrum use with international footprint (satellite, maritime, aeronautical).In addition, reuse of current harmonised WBB ECS spectrum may be considered depending on further broad

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implementation of 5G SA by MNOs and features under standardisation for intra-MNO coexistence (RSPG's first Opinion on 6G [25]).

Technical advances of current 6G proposals that impact policy questions seem to be limited – as we are given more of the same, as for 5G in the draft report. Thus at a policy level, the advance of 6G into new modes of operation is disappointing due to these missing advances:-

1 Complete **spectrum sharing** at general operational level is not considered

2 **Design for cybersecurity** built into the architecture and not tacked on after as 5G design is trying to accomplish for critical mission networks - because security has become a vital policy goal. One of the wider policy aspects of implementation choice with respect to the cybersecurity impacts (including of spectrum choice) the RSPG do not seem mention the Court of Audit investigations of poor quality of cybersecurity design, structures and implementation of 5G networks in the EU MS and the need to completely revise 5G security. *Surely removing that absence of cybersecurity should be a basic tenet for a 6G design.*

3 Core networks should be advancing to a foundation of **non-terrestrial trunk networks** for regional and global long distance, as some military users are already progressing.

4 Drivers and enablers for 6G (p13)

Overall a chapter on the drivers and enablers for 6G should cover the most important areas for regulators considering future frequency bands for a novel technology to operate. However this largely seems to be absent in the text presented here.

Very early on the 700MHz band is identified as a core necessity (and perhaps with bands below it?), **indicating that for the RSPG, 6G is not going to be very different to any other mobile generation**, be it LTE-A Pro, UMTS, GSM or 5G NR. Here the basis for functional description is just the ITU IMT-2030 document[3], largely shaped by the supply side. But it may not be a source that should be depended on heavily, unless there is far more than a glimpse of a complete specification for an advanced and truly new mobile technology based on the demand side requirements also. 5G has suffered deeply from this problem.

This whole problem is a fairly old item going back to prior ITU deliberations and 3GPP debates, for instance, on VR and augmented reality (from W-Industries originally - and abandoned, for the first time, in 1989) – to add Immersive communication use cases. To say, the least, this is vague, as it does not really help with considering spectrum needs.

On 6G usage scenarios, the chapter is largely theoretical, so implications for spectrum demands are rather speculative. Whether the ITU is the most useful source on real needs is in question, as they lack a competent and reliable needs analysis – so its use cases may be somewhat doubtful, offering a relatively 'blue-sky' approach.

4.3 Sustainability The basic relations of signal and circuit power against frequency and range targets with data rates with indications of information rates set power demand design parameters (where Shannon's theoretical channel limits may apply). The actual constituent elements and final products manufacturing, used, such as rare earth elements and their forage, recovery and processing chains also apply in a lifecycle analysis. But there is no questioning, discussion or indications of how these parameters will affect power demands with frequency and transmission modes and thus sustainability. This has been a major problem with large 5G rollouts (as in China).

[3] ITU-R IMT-2030 framework and timeline; outlines 6G development on an international level, Rec. ITU-R M.2160, Framework and overall objectives of the future development of IMT for 2030 and beyond. https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2160-0-202311-I!!PDF-E.pdf

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Note, from EU observer studies of standards for sustainable systems and ICT's this approach may be symptomatic of supply side considerations of sustainability. Possibly the real meaning of a sustainable generation of radio systems is not taken very seriously. And hence there are no recommendations - significant and realistic suggestions seem to be absent here. Going back to first principles of electronic systems design in terms of comparing today's and simulated future power demands would be useful, with the interpretation of extensions of functionality in terms of power required (eg for beam forming to get the range and throughput with multiple-input–multiple-output antennae being necessary). Moreover the general consideration of low power design is absent. For instance, concepts of the implications of converting to adiabatic logic technologies for the frequencies envisaged would not appear to be entertained.

5 Spectrum sharing options p17

Various major recommendations in this area do not seem to have been taken very seriously[4].

Whether the role of the RSPG is being fully pursued is unclear in bridging the regulatory requirements of governance, the supply side demands, with the MS administrations' pressures for spectrum fees as well as the industrial policy of the EU. This is a problem, as spectrum sharing could form a much more constructive support for future spectrum use, especially for relay or device-to-device mode of communication, sidestepping the base station centred RAN model. Mobile network systems can then offer frequency diversity, NOT-SPOT infilling, management of alternative traffic streams for capacity relief, extension of network coverage and emergency services, and avoidance of infrastructure duplication in expensive to cover remote regions. Within closed user group configurations it may even provide the possibility of free mobile (unbilled) communications. It can also use unlicenced spectrum for increased data traffic capacity and RAN/Core offloading in cases of traffic saturation – eg at public events in a closed area.

6 Strategic Role of Non-Terrestrial Networks in 6G p22

This at least is a significant subject area that any 6G prospective spectrum demand and usage analysis should cover. It needs to have added an engineering-based overview description of how ground-space networks will be configured. Some of the accounts of the various in-space/ and stratosphere resident transceiver vehicles are interesting. They might eventually offer broadband coverage for land, sea, air communications as well as in space. And they could stretch to other types of user (PPDR, marine, etc)

However, the economics, long term, compared with terrestrial and subsea (cabled strung and buried) for mobile core and RAN capillary networks will be the determining factor. That is not mentioned in the analysis from the capex /opex/coverage perspective. It is the key point.

The emergence of non-terrestrial civilian consumer networks that interact with terrestrial customers has been a major subject for novel network architecture engineering since around 1998. In that time, the prices for a kilogramme in orbit have fallen from millions to under 1% of that today (but only for some commercial USA systems such as Space-X, for Starlink, but with Kuiper expected across the EU perhaps in a 2026 timeframe with Spacesail from China in the background). However, retail price projections for the next 5 years for a *competitive market*

[4] For instance on the various aspects of shared spectrum, *"Perspectives on the value of shared spectrum access*" (SMART 2011/0017), SCF Associates Ltd: emphasised the approaches, returns and industry impacts of shared spectrum deployment, Information Society and Media Directorate-General, Electronic Communications Policy (DG CONNECT, *Unit B4, Radio Spectrum Policy)*

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are expected to drive a decimation of that base cost by 2030. Moreover expenditure on the two main components that are not mentioned here should be explored further:–

- The in-space long distance optical network (comparable to a core network but global wide) based on directional laser optics could offer enormous capacity and global reach at low cost compared with subsea cabling and terrestrial broadband trunked networks.
- Beamed links to terrestrial users, with variable costings, of the order of 150 - 500 Euros per month today but possibly dropping quickly in a competitive market. The interesting aspect is how fast could it fall across the EU as at least five competitors with EU landmass coverage may be expected after 2029. Their demands for new spectrum could be minimal, depending on beam width and physical attributes.

7 Role of the authorisation regime p24

The authorisation regime for a new mobile telecoms generation should cover a number a very different subject areas. The subjects chosen here are quite diverse, ranging from technology neutrality of bands, to spectrum sharing to the need for national implementation of European Recommendations on licence-exempt use and the policy effects of the single market. Spectrum sharing should figure here prominently. These are valid areas for preparation of a new 6G generation. However without a better definition of 6G aims, business models and technologies, with their implementation, then the subjects mentioned here are somewhat theoretical for an authorisation regime discussion.

Moreover, today's authorisation regime is expanding in form and function. How national regulation will mesh with in-space systems should be considered, for instance. That could be covered by a common EU approach, hopefully, but some MS may have specific .measures and restrictions, which could overlap with non-mobile radio users (aeronautical, marine systems, civil defence, etc)/ That includes the spectrum used by LEO mobile systems that could replace terrestrial mobile with direct access beams.

The use of device to device (relay D2D) systems also opens many new considerations, and problems, from billing to permission to use handsets, to privacy. This may also be coupled to Licence-Exempt (LE) use, perhaps with simultaneous sharing. It could become a more complex authorisation area if 6G introduces new approaches to use of shared frequencies. Station discrimination (fixed and mobile) may depend on new operating modes opened by innovative approaches with dynamic adaptability. That may introduce far more LE spectrum use - or mixes – that is an interesting development but does introduce novel authorisation models. Depending on the frequency range employed, the use cases and other requirements for LE use may a first choice and/or a complementary solution to the licensed use of spectrum.

Also there is a need to consider novel EMF-aware 6G regulations due to parallel networks, for network planning, and for site selection for 6G BTS, for the authorised downlink EMF limits. To this end, it will be necessary to present the current state of the art in EMF-based design for mobile networking, and an overview the current exposure limits and how the EMF constraints may impact 5G planning.

Authorisation should also cover the 6G network deployment with installations of new and different base station (BS) equipment. However in a context of multiple sources of radiation from communications, EMF sources would include any overlapping 2G/3G/4G/5G signals (plus other radio technologies - from NFC to Wi-Fi, up to Gigabit speeds often in their assigned licence exempt bands) of competing network operators. Hence there will be a concern that the planning of 6G networks may be set by the limits on maximum EMF levels established in across a wide set of regulations, including those based on ICNIRP thresholds.

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8 Input from R&D p26

Potentially this chapter should be one of the most useful of the subject areas analysed as it points to the future capability of what 6G is currently imagined to deliver, by the RSPG sources gathering future spectrum demand estimates.

Regrettably, this not really the case. However the chapter could be more useful if it were based on far wider and deeper sources than apparently a few similar ‘industry research’ projects and one academic project. These have tended to choose what they see as unused spectrum bands – centimetric, millimetric and Terahertz with lots of bandwidth being offered and high bandwidth assignments being possible. The comment could be made that these are available for jolly good reason – their propagation is limited in range so covering a city and specifically indoor coverage from outdoor base stations is something of a myth (unless the ’city’ is a termite hill). And it is well to note the use of ‘Terahertz’ is being aimed at up to 300 GHz, ie all of 0.3THz). The atmospherics propagation range at fractional THz frequencies is not that of outer space (where electromagnetic propagation is not quickly attenuated by excited molecules getting in the way). The goals for 6G use of spectrum (section 8.2) are quite logical but nothing new – they are the targets for all generations of mobile. The frequency ranges currently under discussion at the international level for 6G are rather as would be expected.

The use cases seem to be leftovers from 3GPP 5G NR NSA and ITU for 5G, 2014. They may be ideal for **5.2G,** but not for a next generation which offers real and significant advantages over preceding generations. Effectively these 6G Use cases have little new. They appear to be a recycling of the vertical applications that demand network integration capabilities of the MNOs (unfortunately, outside their skillsets, business models and finances), high bandwidth, low latency ITU/3GPP models of a decade ago, probably because there is little new in available research so far. They offer a lack of innovative architectural thinking. In practical terms, ie - *NO “big picture” of the future* has been painted for innovators to fill in.

However some of the subjects in this section do cover real issues – although many may not be in realistic ways, unless we are considering a 5.2G release as 6G. The section on launch readiness for 6G in 2030 for the mass market for services and equipment is useful in being a little more sensible about the real issues of network deployment generally (security, vulnerabilities, SPOFs, energy consumption, radiation levels, traffic capacity, rural coverage at low cost, indoor traffic (the 80%) and assuming that EU MS can have have a uniformity of spectrum bands. But some subject areas stray off the mark of real innovation (eg edge computing impacts have been around since 2000 and are not really an innovation any more). Research challenges for security and privacy are mentioned but the need for building mission critical networks with high resilience is not seen in real life terms, ie, as if it is the ‘*point de depart’* of network strategy.

Nevertheless, the spectrum implications of some of the use cases may become more realistic, in that they at least recognise the increasing physical constraints of upper bands and the attractiveness of lower bands. But the concepts here still sees the limits of data rates as a problem, not expecting any advances in 6G technology for signalling. It is understood that coverage is crucial noting that indoor coverage as well as remote and rural area coverage present challenges and should be a priority for any 6G system design.

Predicting capacity needs for 6G certainly does have a lot of uncertainty, as the current use cases for the 2030s, on future service and technology development, seem to be developed from the current traffic forecasts. Using the ITU-R’s IMT-2030 publications as a foundation for decisions may prove to be problematic, without the demand side. Increasing the future role of spectrum sharing calls for understanding what spectrum

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sharing means in the future markets and its implications on technology, regulation and cashflow (including auctions costs), which is still a challenge.

9 Input from equipment manufacturers and operators p 35

The major problem with using the supply side is that it tends to base projections of future systems and technologies on what it wishes to sell, not what the intermediaries (– telecoms operators and to some extent the platform operators) want to buy - and *certainly not* on what consumers will be looking for.

For instance, the end user needs useful functionality, high reliability for years with strong security, so it has non-invasive and non-threatening impacts on everyday existence, at low cost, with stable, useful technical features. These new network systems should be simpler to use, with intuitive human interfaces, for all the principal ages of user.

In summary, the real question is where is the input from the demand side?? Unless real demand for this new design of mobile network can be shown, any predictions of spectrum demand id difficult take seriously.

10 Spectrum for launching 6G in the EU and paving its initial development p36

The section covers five fairly useful subject areas:-

- The timeline for development of a (robust) 6G network system – really trying to see whether 2030 is realistic – this is quite unlikely judging by the progress so far unless it is a small upgrade on 5G so far, especially with the need for not just network infrastructure but also for consumer handset devices and integration with other complementary environments, especially the LEO networks. The timeline also sets the pace for releasing relevant bands for spectrum access. Obviously WRC 2027 will be important. Note that this could be slowed if 5G rollout takes precedence – incompatibilities and dependencies would have to be anticipated if a 5.2G is the target – and upgrades would have to be assured with engineering of backwards compatibility for infrastructure re-use.
- Densification of public mobile networks – this activity depends on the technology resemblance of 5G today to 6G as a 5.2G upgrade.
- Spectrum for 6G for the launching phase – this assumes that 6G has no spectrum efficiency engineering so that wider spectrum bands are used as the engineering model used here is bandwidth equates to data speeds and to capacity so 6G will demand more
- How to respond to 6G spectrum needs – this relies on switch off of prior generations and perhaps 5G: whether the MS - and their economies agree - is yet to be negotiated
- Need for coordinated timing on new bands – an unsynchronised spectrum feast (by MS)
- Creating a 6G eco-system supported by policy initiatives – the need to synchronise rollout/ customer demand/ handset manufacture and halting of 5G (first generation) rollout so '6G' can be deployed has calls for EU policy support with a 2030 deadline.

In practical terms this seems ambitious as it requires much work on spectrum switchover coordination. In realistic terms, it seems high risk with much effort for a system that will not achieve enormous advances, from the description seen so far. So the reality may possibly be disappointing.

ANNEX National coverage requirements: Finland, France, Germany, p 40
National coverage including main roads, rail tracks are provided with various bands using various mobile network technologies, including 5G. These national coverage requirements are parts of national authorisations and could differ from country to country due to national

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context, needs and policies (see some national examples in annex). Member states data illustrate the potential take off if 5G in the 3.5 GHz band despite C-Band problems for (fixed TV geostationary) satellite and other users.

Initial conclusions on the evidence for 6G spectrum demands as reported here

Calls for spectrum expansion in bandwidth may be unnecessary as far as the evidence presented here shows, as the 6G model could perhaps fail in public take-up in its current form. 5G is not yet widely accepted by many MNOs, subscribers and MS, after 10 years of development and attempts at rollout. This is due to 5G's cost and complexity. Modelling 6G using the 5G mould, ie really as 5.2G, is unlikely to be popular and successful. The reason to take-up 5.2G has not been shown here and so the need for (new) spectrum is in doubt.

In consequence, the EU market will remain with LTE-A-Pro, if this RSPG report reflects the sum of the real evidence for 6G emergence across the EU in 2030. Unless the 6G design envisages new capabilities that the market really wants and demand-side analysis comes up with something far more compelling, 6G planning will not need any spectrum allocation. It will not take off.

Instead, the LTE-A-Pro market's current spectrum bandwidth is likely to remain sufficient. The extensions of LTE-A with spectrum sharing across MNOs (as in France) is the only development impacting spectrum demand - and the effect is to ***reduce*** the spectrum required.

Note that the useful advances listed here could be added to LTE-A Pro. But that is not '6G' in terms of major advances in capabilities, security and costs. LTE-A Pro extensions include:-

- LEO interfacing
- Shared spectrum
- More use of LE spectrum
- D2D for relay systems (in LE or the native spectrum)

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