Thoughts on Standardization of a Spectrum Sharing Solution for 5G

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IEEE 5G-IoT Summit Helsinki
Helsinki, Finland, 18 September 2017

Spectrum is (Still) King

- A key to the realization of capacity requirements for 5G is spectrum.
  - Getting closer to Shannon limit (depends greatly on how you assess that!).
  - Extra capacity extracted through, e.g., (massive) MIMO and full-duplex communications, decoupling, etc., promising but have challenges.
  - Increases in frequency reuse to enhance area-capacity can only serve as the solution up to a point.

- Millimeter-wave ("pioneer bands") are a vital part of 5G, e.g., because of the extra spectrum that they imply, will not be the end-all solution to capacity requirements.
  - E.g., in addition to increase in density of base stations, will be coverage gaps and capacity uncertainty in millimeter-wave deployments due to propagation issues—no matter what "smart" mechanisms you employ.

- → Use of lower-frequency spectrum will still be necessary to realize 5G capacity, signalling requirements (i.e., reliability aspect), in addition to millimeter-wave and a plethora of other solutions.

- → Low frequency (<6GHz, or even < 3 GHz) spectrum is still king.

And Spectrum Sharing Can Make Spectrum a Good King

- Emphasized in a number of key reports that spectrum sharing is a primary method to make more such “beach-front” spectrum available.
  - President's Council of Advisors on Science and Technology report on “Realizing the Full Potential of Government-Held Spectrum to Spur Economic Growth” in the US.
  - European Commission Communication on “Promoting the shared use of radio spectrum resources in the internal market” in the EU.
  - Radio Spectrum Policy Group (RSPG) “Opinion on DSM and Framework Review” in the EU.
  - Numerous reports/consultations, etc., by individual regulators (e.g., FCC in US, Ofcom in UK, Ficora in Finland, etc.).
- As well as use of other services’ spectrum (even without agreement of the other services, mandated by regulator), can apply to agreed sharing among 5G and other spectrum owners.
- Also enhanced sharing in the context of unlicensed/light-licensed spectrum.

Geolocation-Based Spectrum Sharing is One Example of a Good Kingdom

- Smart spectrum sharing approaches release a lot of spectrum (UK TV White Spaces Pilot: Examples from our trial).
- King's College London has led a major trial of TV white spaces technology within the Ofcom TV white spaces pilot. E.g. (among others),
  - O. Holland, et al., "TV white space in London, UK: availability and maximum achievable capacity", Electronics Letters, Vol. 51, No. 12, May 2015.
  - O. Holland, et al., "To White Space Or Not To White Space: That Is The Trial Within The Ofcom TV White Spaces Pilot", IEEE DySPAN 2015, Stockholm, Sweden, September-October 2015.
  - O. Holland, "Some Are Born With White Space, Some Achieve White Space, and Some Have White Space Thrust Upon Them", IEEE TCCN Transactions, June 2016.
  - O. Holland, et al., "Changing availability of TV white space in the UK", Electronics Letters, Vol. 52, No. 15, July 2016.

Geolocation-Based Spectrum Sharing is One Example of a Good Kingdom

- Assessed London M25 area, top-left corner (lat, lon) 51.678064, -0.506744, bottom-right corner 51.312133, 0.22934, sampling “spatial frequency” 0.01 degrees equally in latitude and longitude. 2,775 samples total for each of the assessments on a London-area basis

Geolocation-Based Spectrum Sharing is One Example of a Good Kingdom

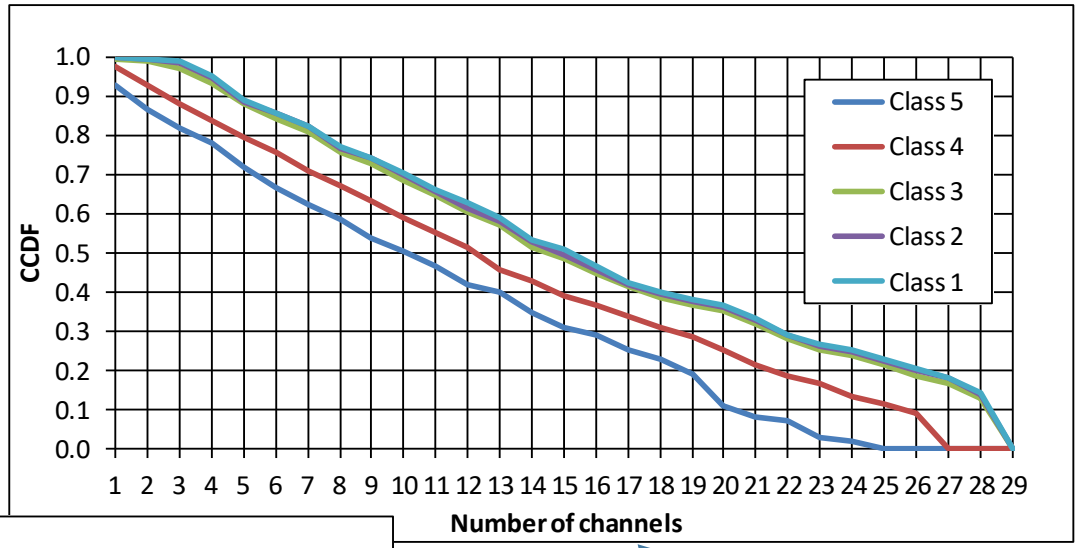
- Scenario configurations

	Trans. Ht. (m)	Rec. Ht. (m)	Trans. Dist. (m)	Req'd. EIRP (dBm)	Path Loss	Shan. Eff'cy
Macro-cell (downlink)	30	1.5	2,000	>30	Hata large-city urban	0.5
Indoor small cell	1	1	80	>20	Yamada, 8 walls, same floor, King's College Strand parameters [14]	0.5

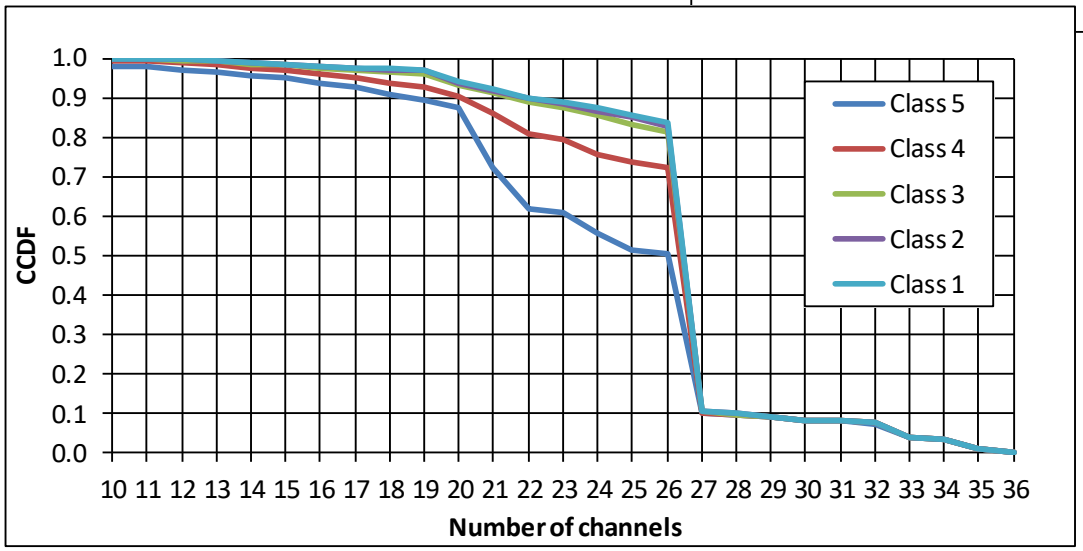
[14] W. Yamada, …, O. Holland, et al., "Indoor Propagation Model for TV White Space," CROWNCOM 2014, Oulu, Finland, June 2014.

Geolocation-Based Spectrum Sharing is One Example of a Good Kingdom

- CCDFs of available channels for the London “M25” area: (a) macro-cell (downlink) scenario (>30 dBm EIRP), (b) indoor small cell scenario (>20 dBm EIRP). Note, class 1 and 2 (and sometimes class 3) device results are often identical.



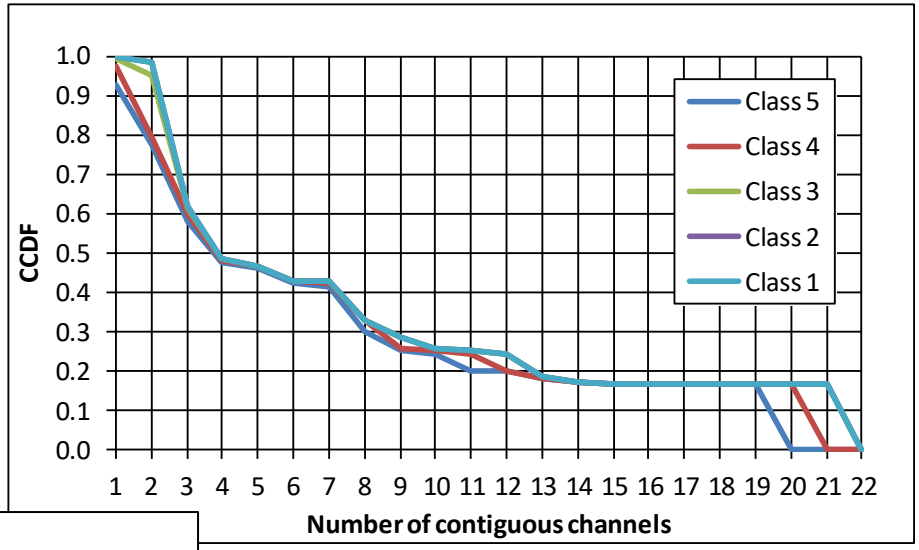
(a)



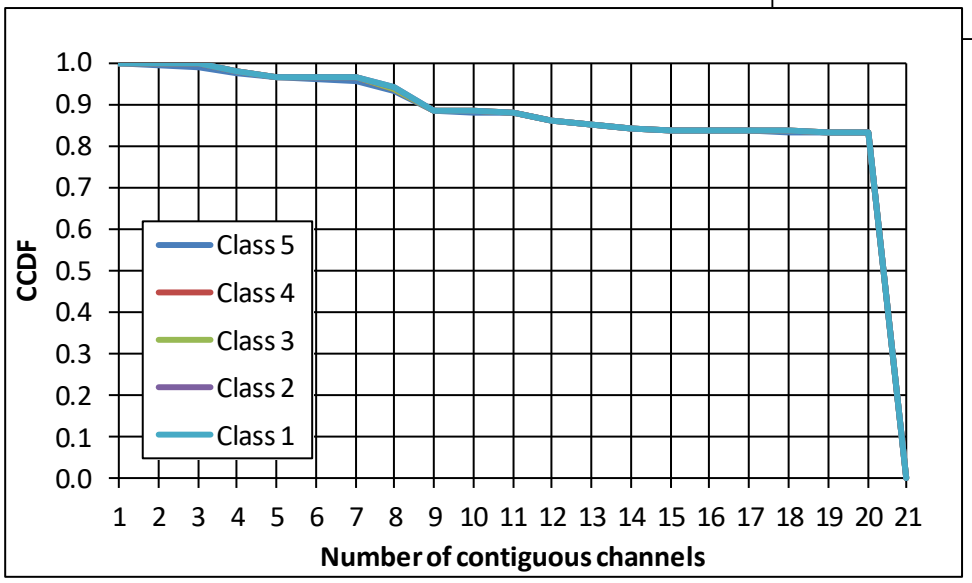
(b)

Geolocation-Based Spectrum Sharing is One Example of a Good Kingdom

- CCDFs of available contiguous only channels for the London "M25" area: (a) macro-cell (downlink) scenario (>30 dBm EIRP), (b) indoor small cell scenario (>20 dBm EIRP). Note, in (a) class 1 to 3 results are almost identical, and in (b) all classes' results are almost identical.



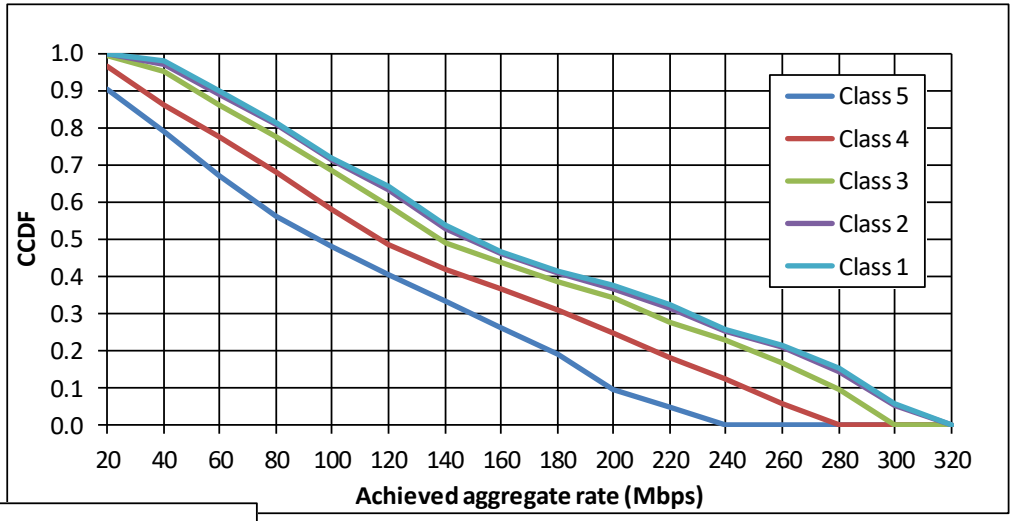
(a)



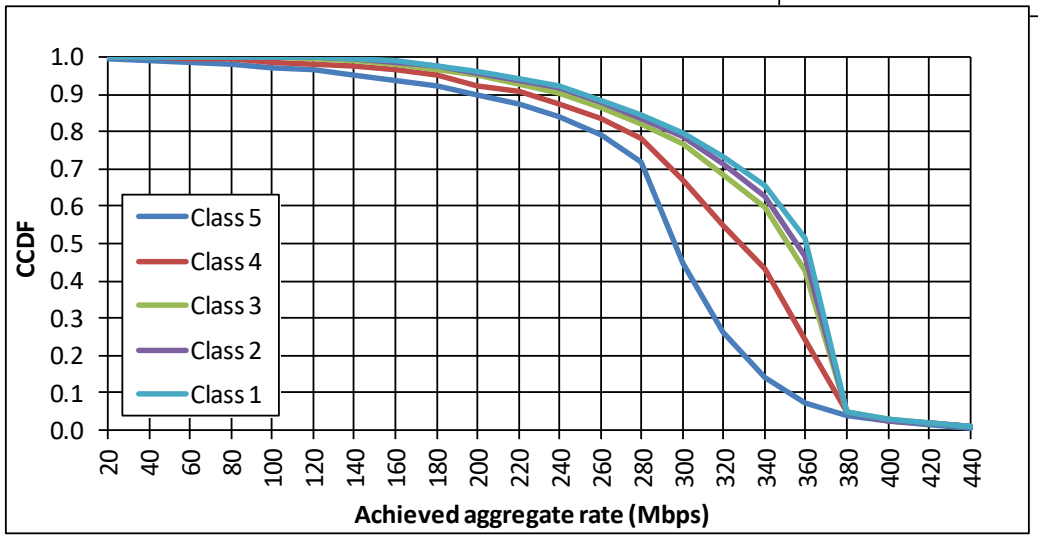
(b)

Geolocation-Based Spectrum Sharing is One Example of a Good Kingdom

- CCDFs of achievable capacity for the London “M25” area aggregating all available channels at maximum allowed EIRP on a per-channel basis: (a) macro-cell (downlink) scenario, (b) indoor small cell scenario.



(a)

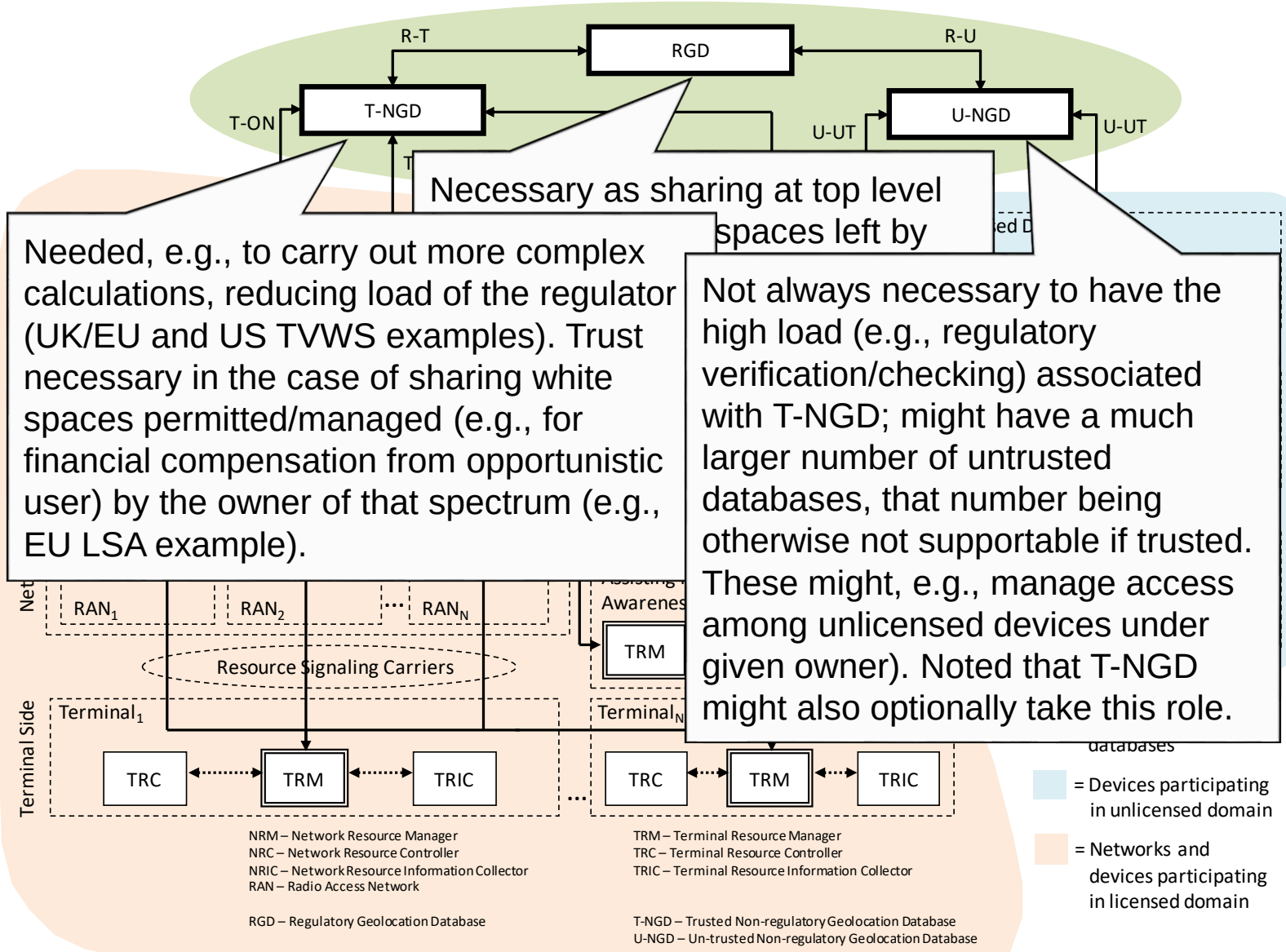


(b)

Such Databases are Far More than TV White Space

- FCC 3.5 GHz three-tier sharing (CBRS) is example.
  - Essentially geolocation database-based, assisted by sensing information for specific purpose of (secure) protection of naval radar.
  - UK (Ofcom) recent consultation on similar approaches for flexibility in 3.8–4.2 GHz.
- Licensed Shared Access (LSA), under broad interpretation of such a database and/or future expansions on the concept.
- Light licensing.
  - Driven by database or other repository cataloguing where co-primary licensees are.
  - In some cases attempt to control interference between the co-primary licensees in allowing new licensees. In some cases the control is done automatically by the protocol of the wireless system that is used.

Geolocation-Based Architecture (with synergies to IEEE 1900.4 standard)



Suggestion

- Geolocation database-based management system, ultimately regulatory-controlled (e.g., TVWS case) but potentially also existing under the domain of spectrum owner (e.g., akin to LSA cases), is ideal starting point for the management of spectrum sharing in a 5G context. **Standardization (by the IEEE? –E.g., under scope of DySPAN-SC?) and regulatory enforcement of such a solution should apply (one possible example: expansion of 1900.4 with analogue to such databases, ETSI EN 301 598 and PAWS (mandated), perhaps unlicensed spectrum sharing, etc.).**
  - Links well with regulator, extending regulatory approaches (necessary for many forms of sharing, e.g., of spectrum of another service).
  - Has been proven in contexts such as TVWS trials in the US, UK, Singapore, Japan and other areas; also more recently CBRS in the US (LTE band exists for CBRS).
  - Also proven in other contexts such as Licensed Shared Access—pertinent to agreed sharing between spectrum owners.

The End…

Thank you!

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Acknowledgement

This presentation has been formed in the framework of H2020-ICT-2014-2 project 5G NORMA. The authors acknowledge the contributions of their colleagues in NORMA, although the views expressed are those of the authors and do not necessarily represent the project. This information reflects the consortium's view, but the consortium is not liable for any use that may be made of any of the information contained therein. Some of the ideas in this work have also been supported by the ICT-SOLDER project, www.ict-solder.eu, FP7 contract number 619687.

Book

- A detailed coverage of aspects of TV white spaces and other solutions for opportunistic spectrum sharing
- O. Holland, H. Bogucka, A. Medeisis (Eds.), *Opportunistic Spectrum Sharing and White Space Access: The Practical Reality*, Wiley
- Available now
- 26 chapters covering hardware/software solutions, deployments and trials, mechanisms and algorithms, business, policy and market solutions, standards, deployment scenarios/applications, etc.
- http://eu.wiley.com/WileyCDA/WileyTitle/productCd-1118893743.html