DYNAMIC SPECTRUM SHARING IN WIRELESS COMMUNICATIONS
POSSIBLE GAINS AND CHALLENGES

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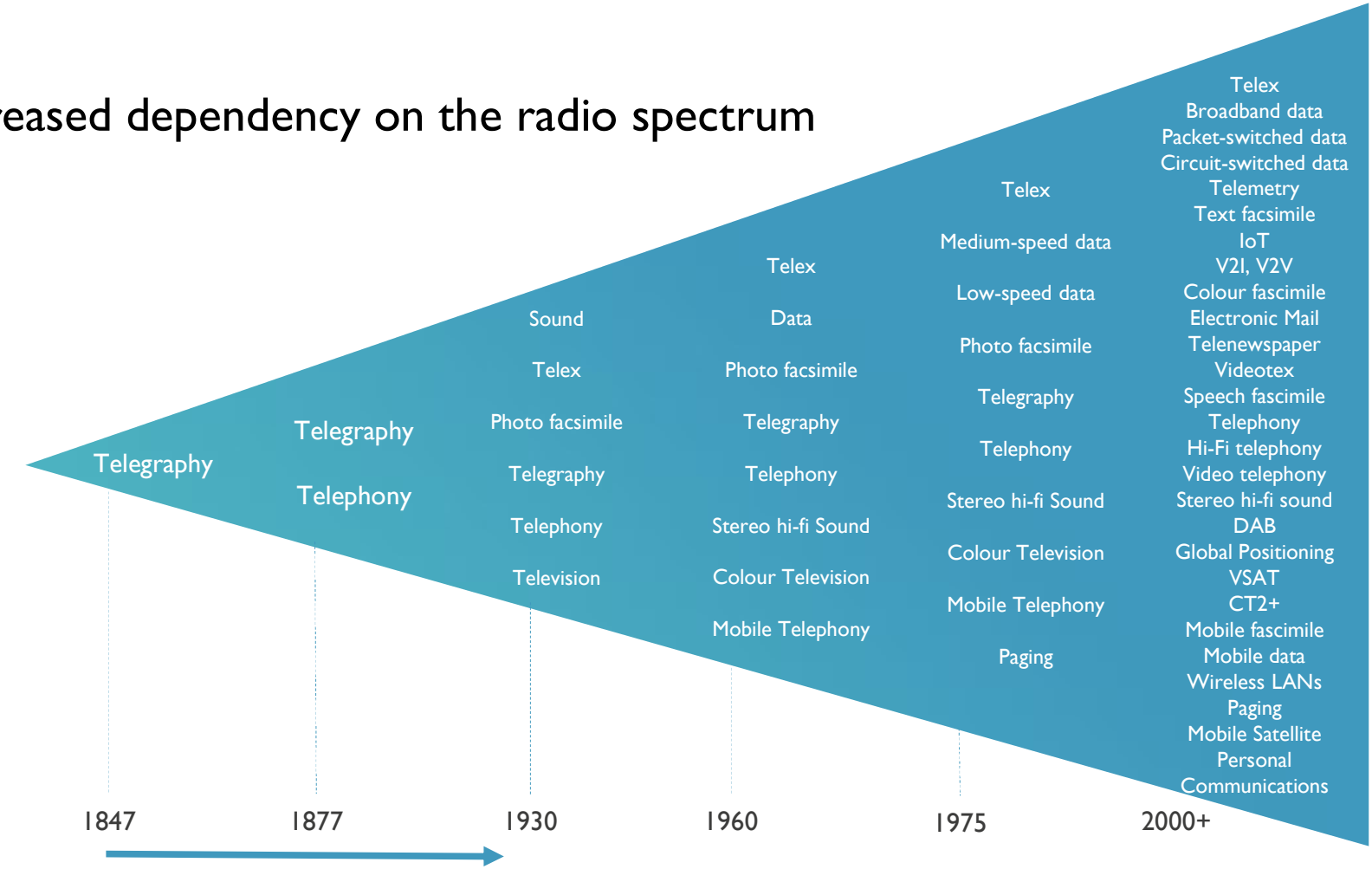
OUTLINE

- Status of Spectrum Sharing in Terrestrial and Satellite systems
- What is Dynamic Spectrum Sharing (DSS) ?
- Why now?
- Enabling DSS
- Gains and Challenges
- EU actions towards DSS
- IMEC achievements on DSS
  - H2020 WISHFUL PROJECT
  - DARPA Second Spectrum Collaboration Challenge
  - ESA CODYSUN
- Take away message

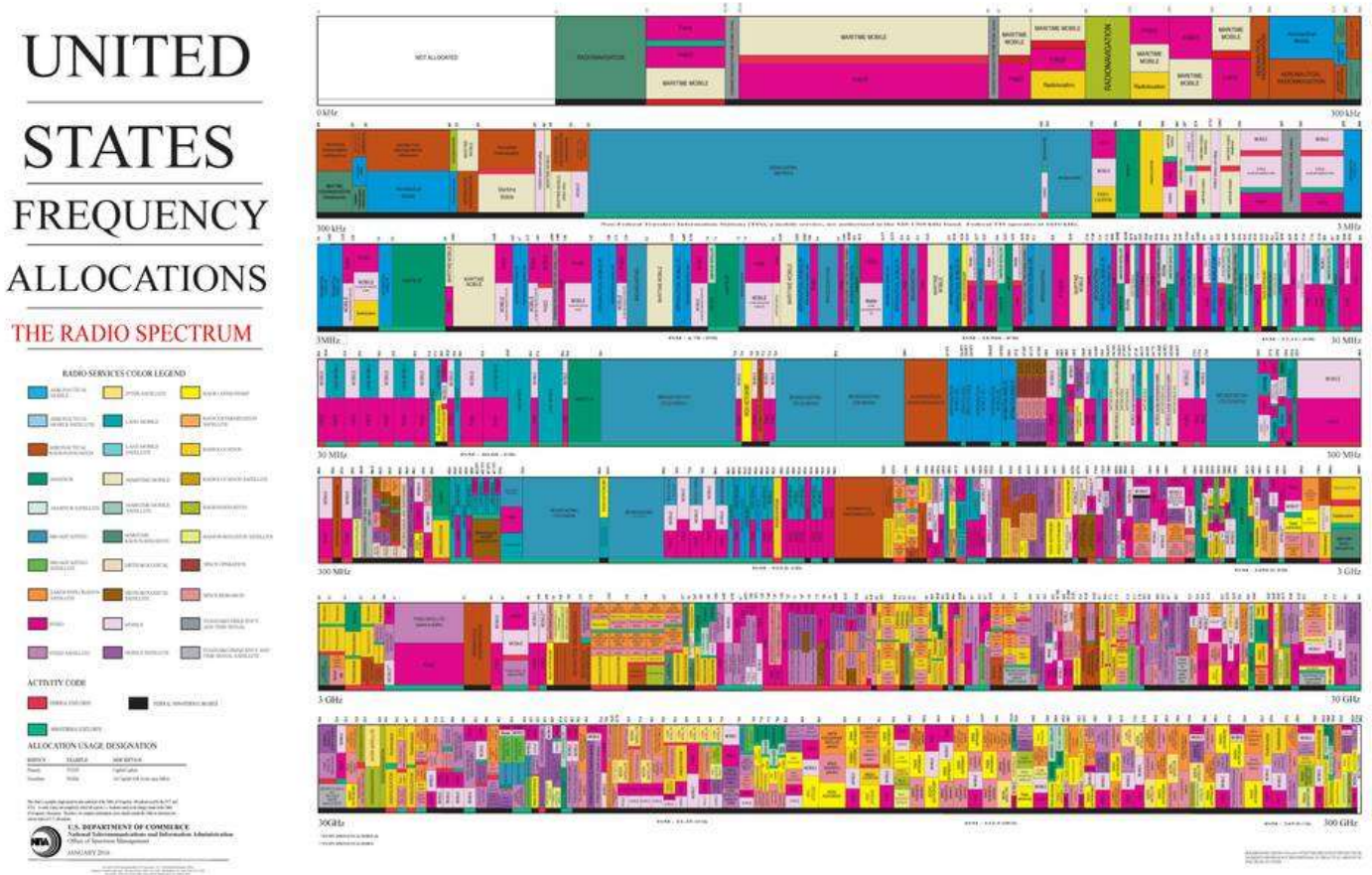
STATUS OF RADIO SPECTRUM

SPECTRUM DEPENDENT TELECOMMUNICATIONS SERVICES

- Increased dependency on the radio spectrum



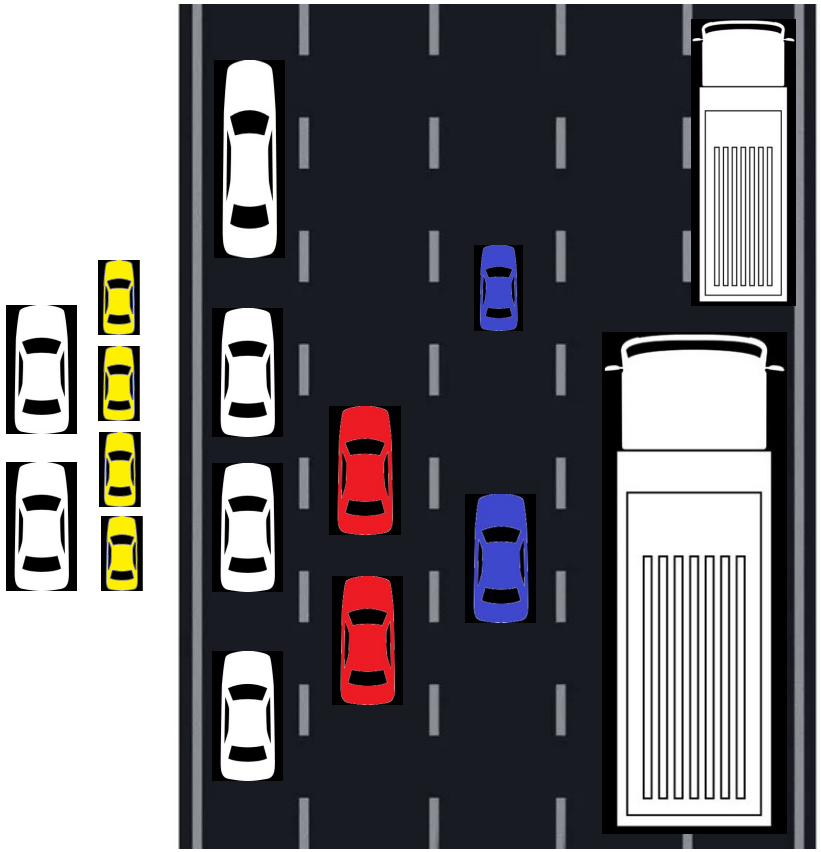
FIXED SPECTRUM ALLOCATION IS THE NORM TODAY



DSS IN A NUTSHELL

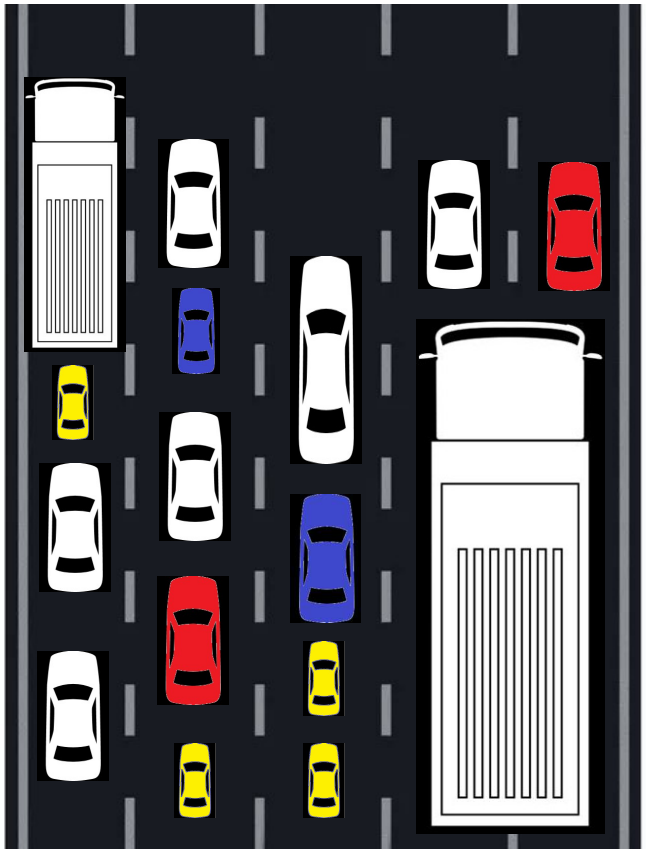
A ROAD-CAR ANALOGY

Today



VS

A DSS enabled tomorrow



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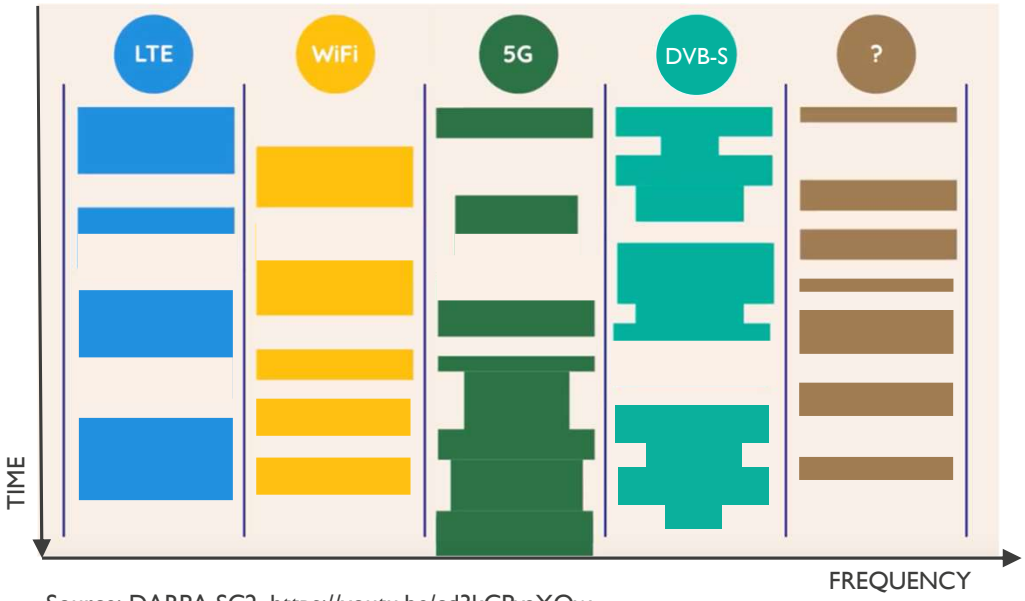
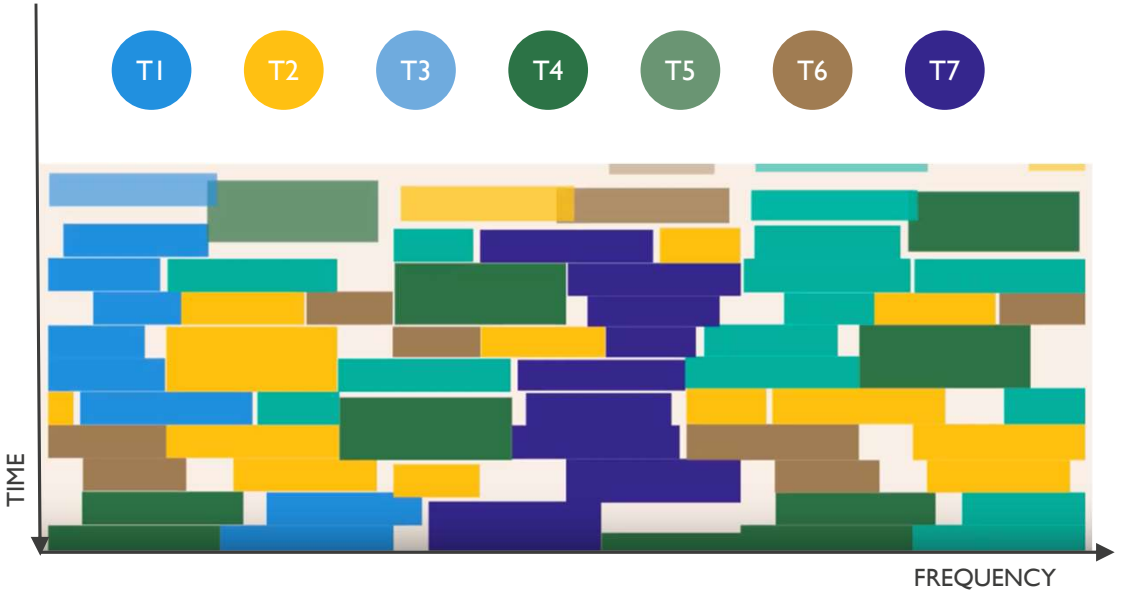
WHAT IS DYNAMIC SPECTRUM SHARING

MOVE AWAY FROM ISOLATION OF SPECTRUM

ISOLATION → AUTONOMY & SPECTRUM COLLABORATION





Source: DARPA SC2, https://youtu.be/cd3kCPvaXOw

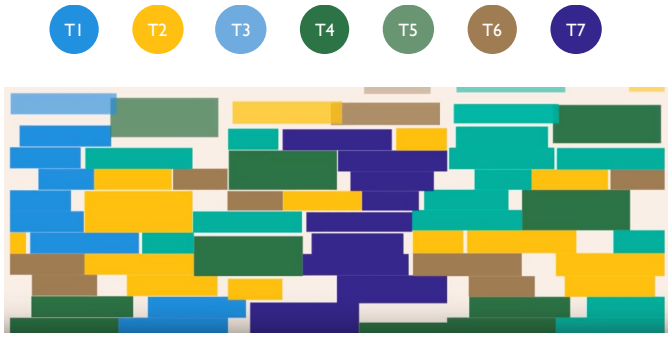
Spectrum silos lead to over-dimensioning and waste of spectrum

DYNAMIC SPECTRUM SHARING

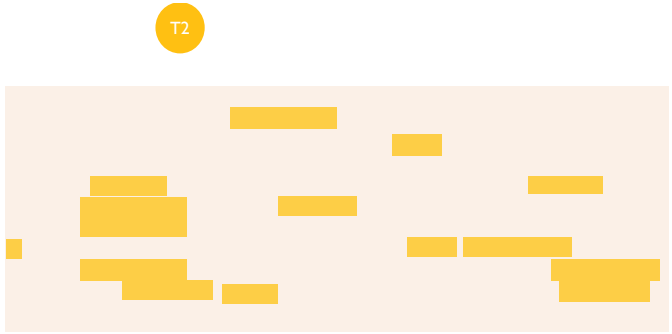
LARGE POOL OF RESOURCES

DARPA SPECTRUM COLLABORATION CHALLENGE

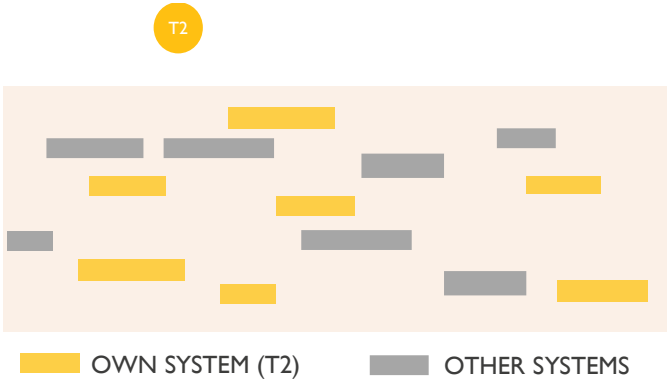
Global view



Single System View



Single Rx view



Large pool of shared spectrum + spatial reuse = freedom for resource allocation

Why single Rx view? → INTERFERENCE IS PERCEIVED ONLY AT THE RECEIVER!

DSS takes advantage of Time-Space-Frequency planes and reuses spectrum slices

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Source: DARPA SC2, https://youtu.be/cd3kCPvaXOw

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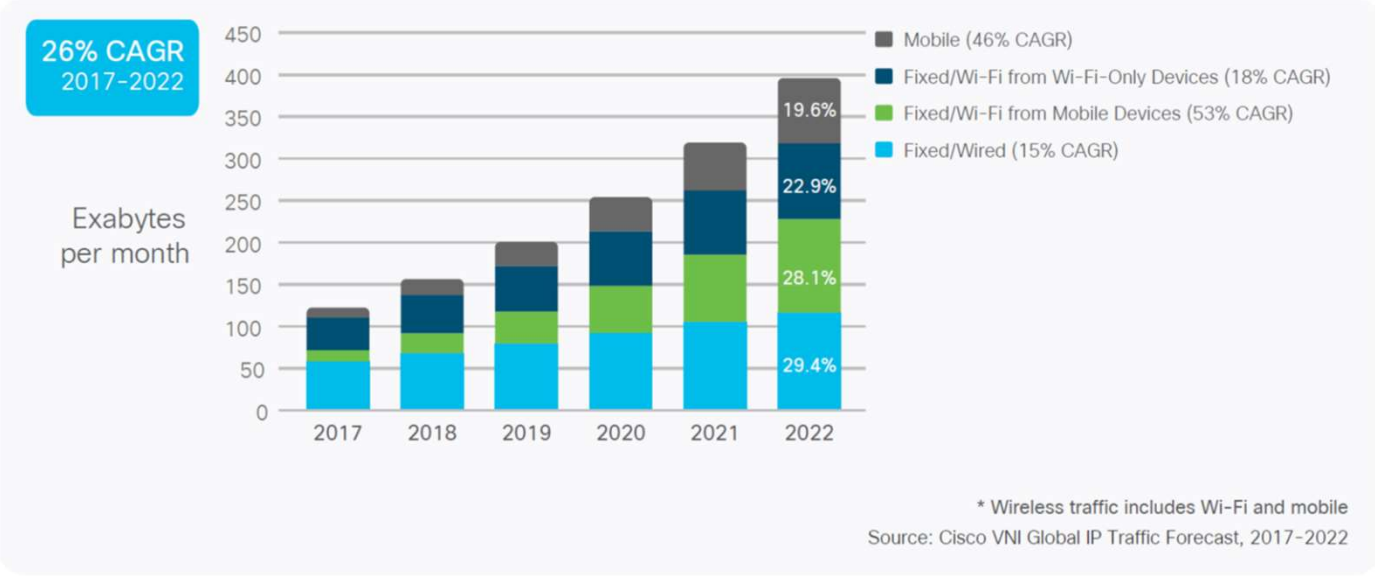
WHY NOW ? TERRESTRIAL DOMAIN

SPECTRUM DEPENDENT TELECOMMUNICATIONS SERVICES

- Wi-Fi and mobile traffic **growing faster** than fixed traffic
- **Fixed traffic** fell from **52%** of total IP traffic in 2017 to **29% in 2022**
- **Wi-Fi** traffic accounted for **almost half (51%)** of total IP traffic in 2022
- **Mobile traffic** accounted for **19.6%** of total IP traffic on 2022 and growing
- 5G needs **more spectrum**, 6G coming right behind it with needs for ?



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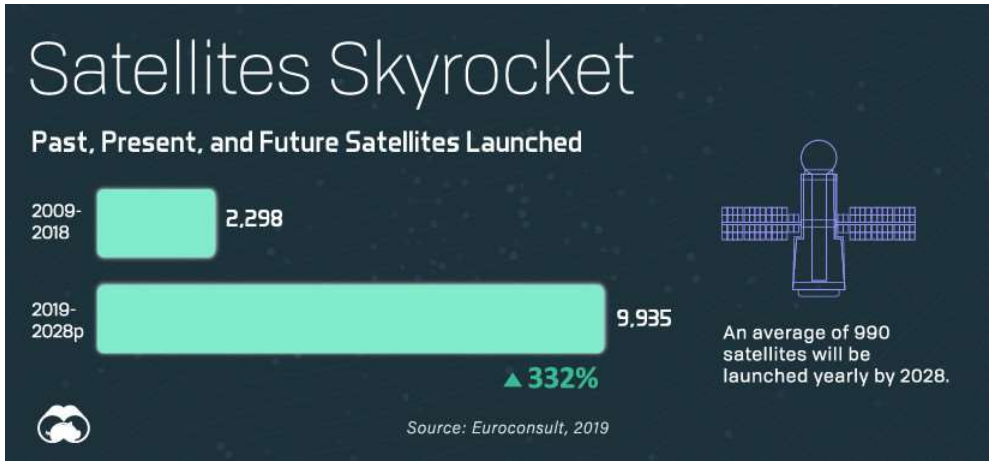
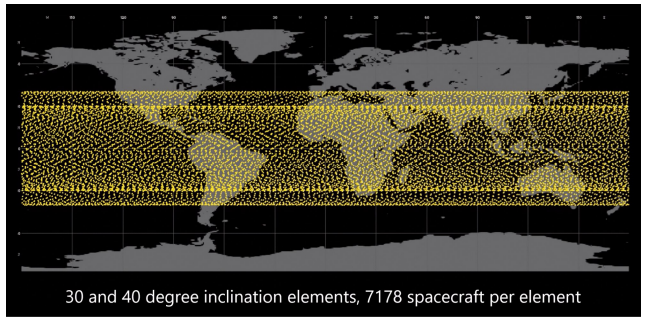
WHY NOW ? SATELLITE DOMAIN

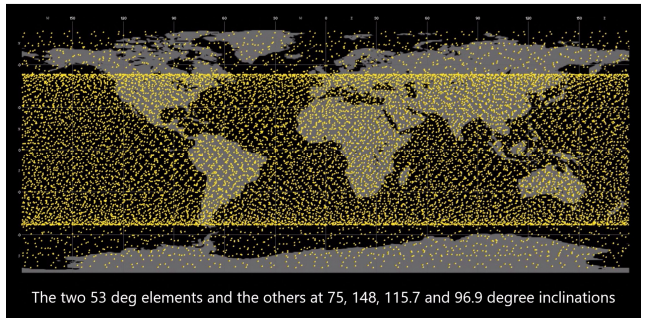


SPACEX alone plans to deploy 30.000 VLEO sats until 2030



2019 projection for ~10k satellites is now updated to more than 40k satellites in total for 2030

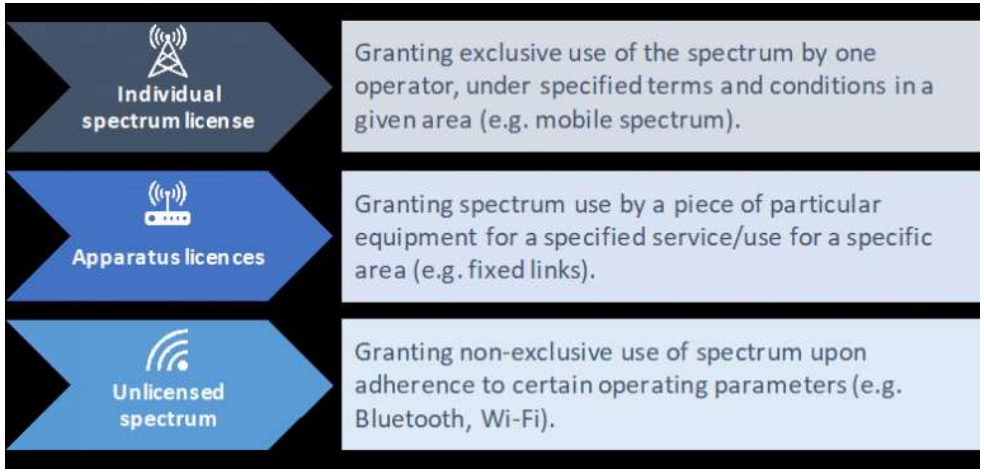
Altitude (km)	Inclination (degrees)	Orbital Planes	Satellites per Plane
328	30	1	7,178
334	40	1	7,178
345	53	1	7,178
360	96.9	40	50
373	75	1	1,998
499	53	1	4,000
604	148	12	12
614	115.7	18	18



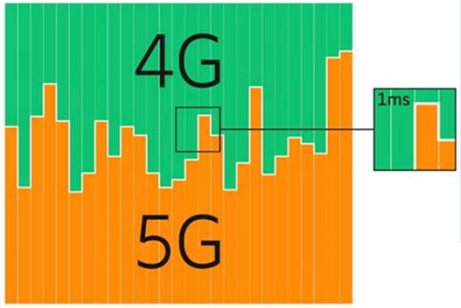
Legacy static frequency/inclination allocations schemes will eventually get saturated

BASIC SHARING STRATEGIES

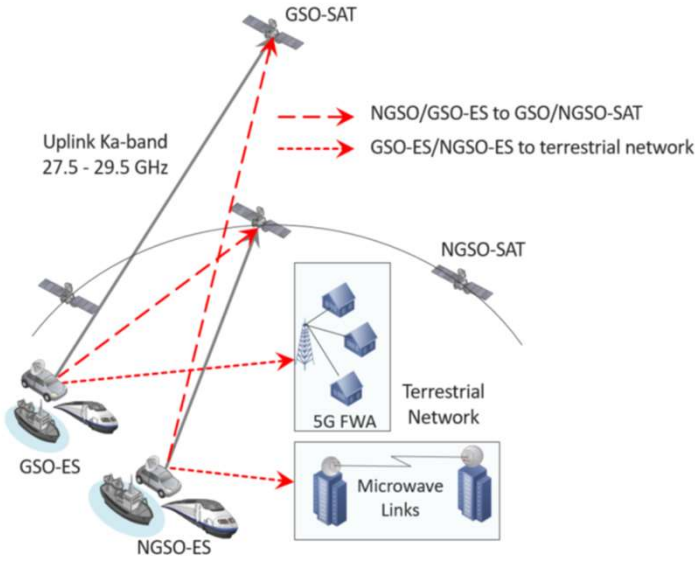
- **ISM bands - Unlicensed spectrum access based on simple rules**
- **CBRS - Specific use case for sharing of military radar, satellite and terrestrial systems**
- **LSA - 4G/5G services sharing within same/co-located operator(s)**

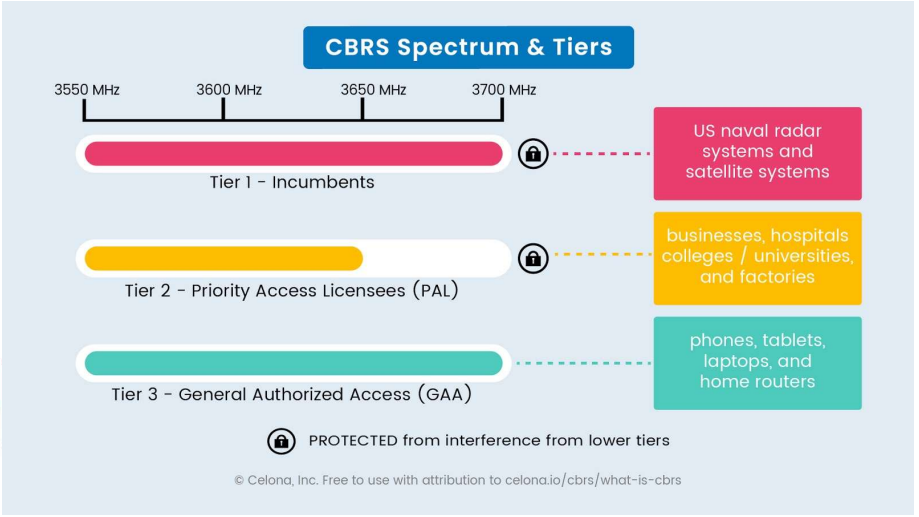


Source: digitalregulation.org



Ericsson's DSS solution dynamically assigns spectrum every millisecond. Source: Ericsson.





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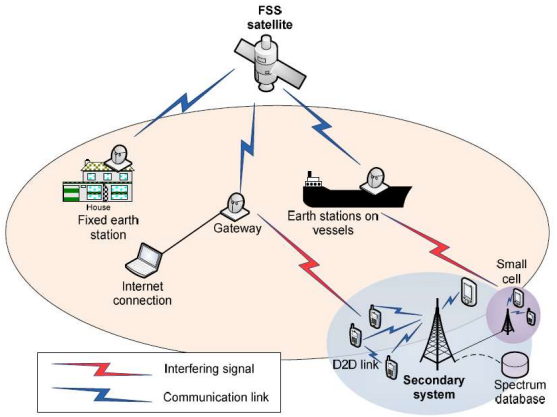
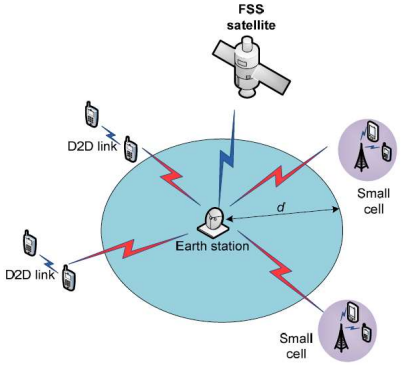
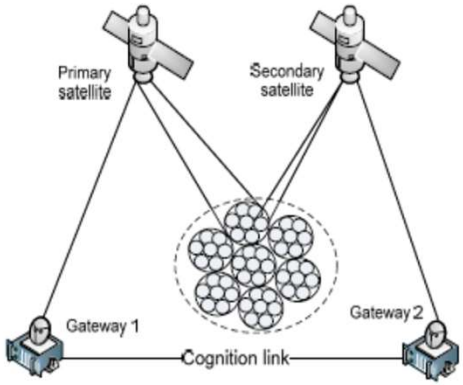
ENABLING DSS
POSSIBLE SOLUTIONS

Coexistence of terrestrial and satellite systems in the same frequency band

- **Uncoordinated systems**
  - Primary/Secondary users approaches
  - Databases
  - Beamforming, beam hoping
  - Spectrum sensing
- **Coordinated satellite-terrestrial systems with CR techniques**
  - Central control entity(ies)
  - Decentralized coordination/management protocols







Source: Hoyhtya et all, "Dynamic spectrum sharing in hybrid satellite–terrestrial systems"

DSS GAINS – ADOPTION CHALLENGES

- **Gains**
  - Able to **resolve interference issues** (from known or unknown sources depending on the approach)
  - **Reuse** spectrum slices, maximum exploitation of inherent spatial reuse potential of sat systems
  - **No need** for man-made frequency-time-space planning
  - **Scales up natively** with network density and scale
- **Adoption challenges**
  - Regulative bodies and industry stakeholders are **very conservative** and PHY layer oriented
  - Best cooperation methods, providing the best results, **require cross-operator spectrum usage data**. This will not get easily accepted from MNOs and Satellite operators.
  - Requires **SW updates** but also **HW upgrades for best results** (SDRs could play a huge role here)
  - **Discontinuous transmissions** is a needed enabler for time division sharing (can be on a later stage)

EU ACTIONS TOWARDS DSS

A VERY EASY SLIDE TO PREPARE

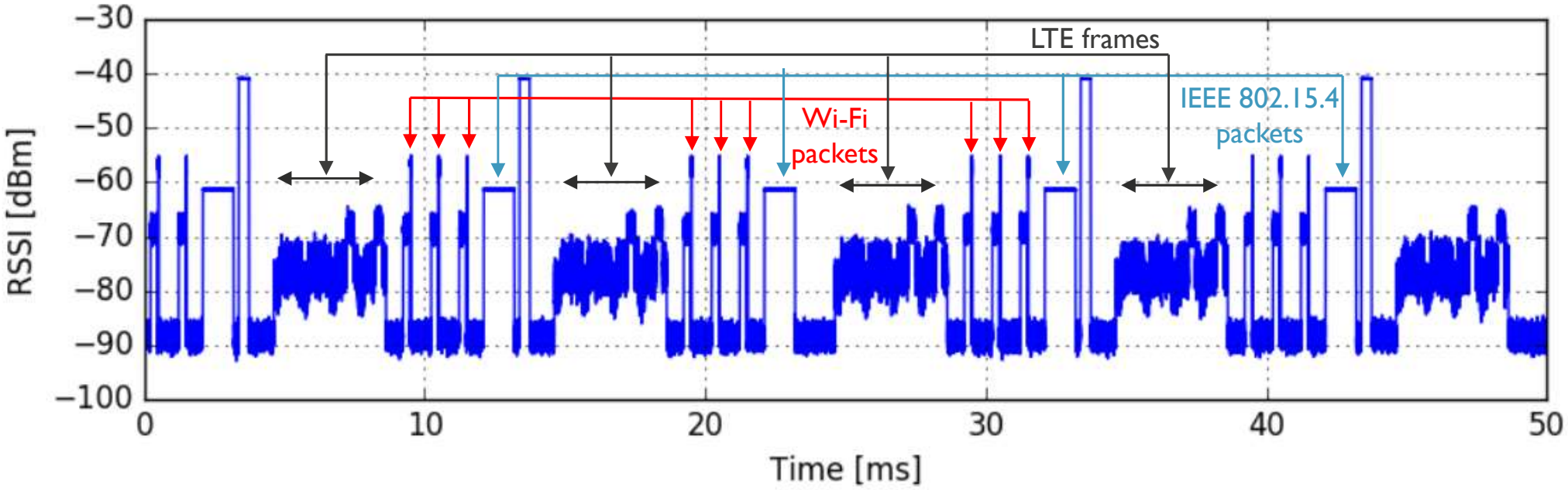
Discussing, wishing and hoping

- In the context of the European Smart Network and Services Joint Undertaking (SNS-JU) related H2020 calls, there is the notion of DSS but mainly between 5-6G deployments.
- The EC Radio Spectrum Policy Group (RSPG) aimed to examine DSS approaches with stakeholders and form an opinion (2021)
  - Spectrum policies should be driven by science and optimal techniques and not only by the mega stakeholders that tend to want to keep the status quo.
- European Space Agency on the other hand is quite interested and working towards enabling DSS in the satellite domain

IMEC ACHIEVEMENTS

THE WISHFUL PROJECT: WIRELESS TECHS COEXISTENCE FRAMEWORK

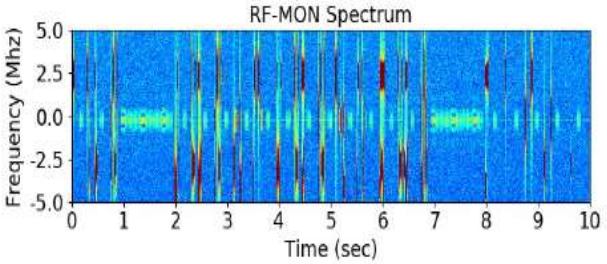
CROSS-TECHNOLOGY SYNCHRONISATION AND 3-WAY TDMA SCHEDULE

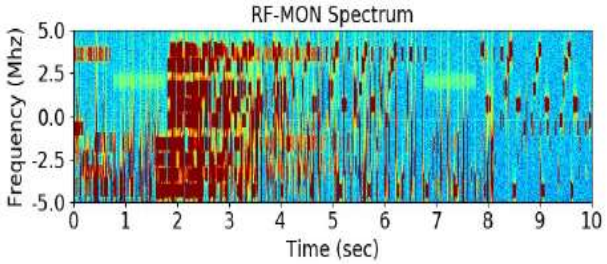


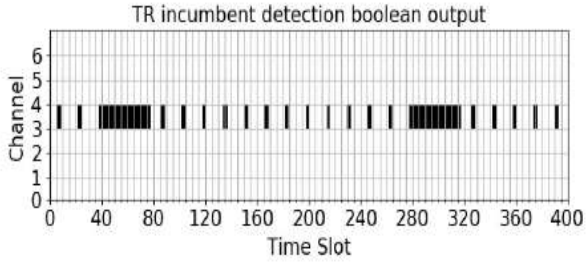
IMEC ACHIEVEMENTS

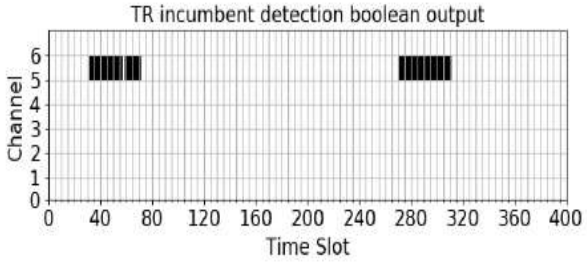
DARPA SECOND SPECTRUM COLLABORATION CHALLENGE

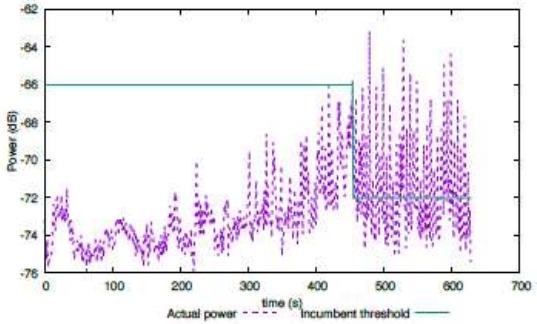
- General PHY agnostic Spectrum Sharing
- Active radar and passive satellite incumbent protection scenarios
- Extreme scalability with fixed management/reaction delay



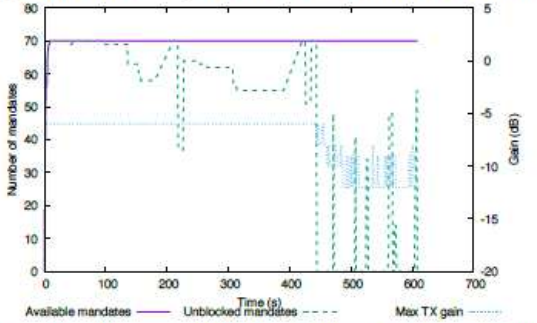




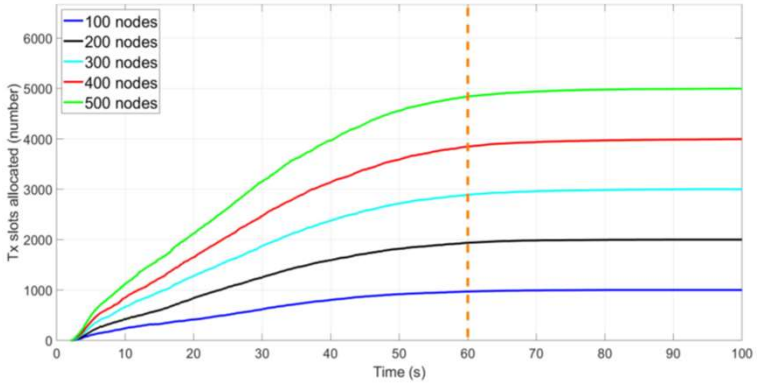




(b) Power measured by incumbent and threshold of incumbent



(c) Active flows and max TX power of the SCATTER system



Tx slot allocation graph for a multi-hop network topology

See for more details: https://ieeexplore.ieee.org/document/9223708
https://ieeexplore.ieee.org/document/9241880
https://ieeexplore.ieee.org/document/9410221

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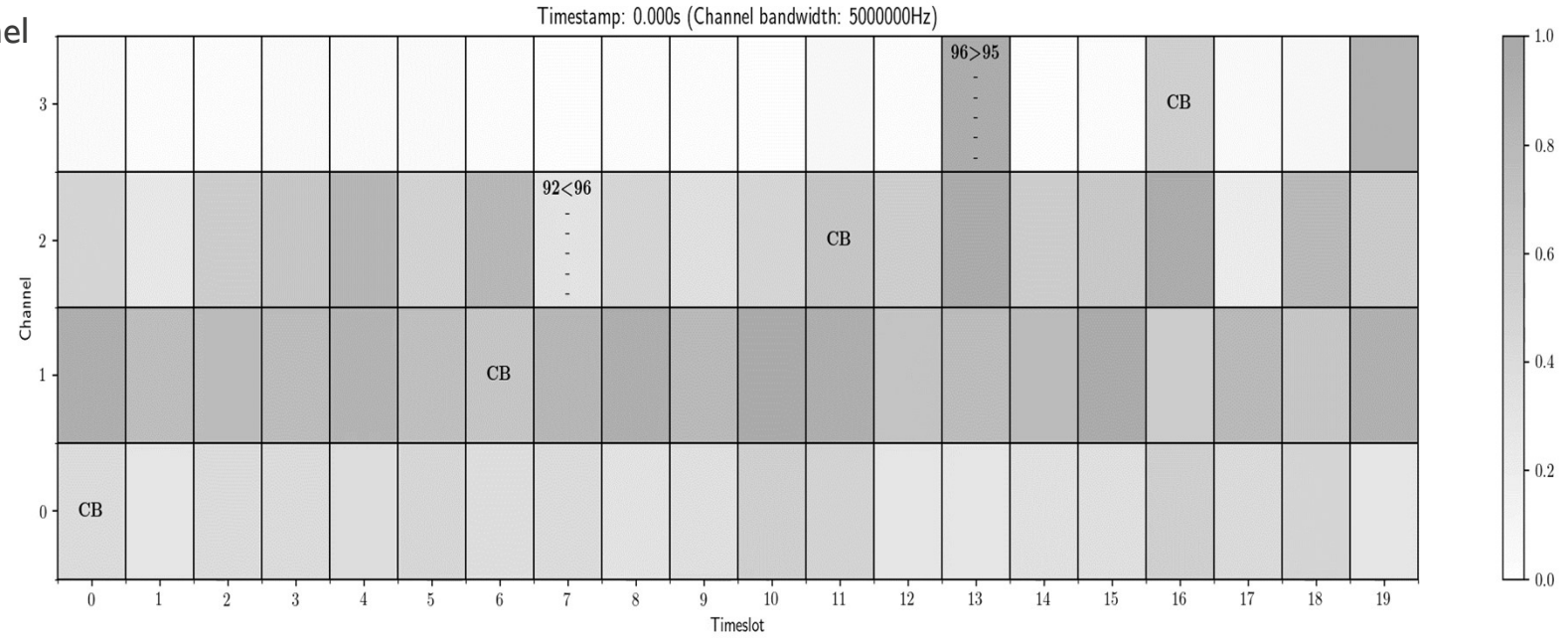
DARPA - SECOND SPECTRUM COLLABORATION CHALLENGE

DYNAMIC DECENTRALIZED SPECTRUM RESOURCE ALLOCATION

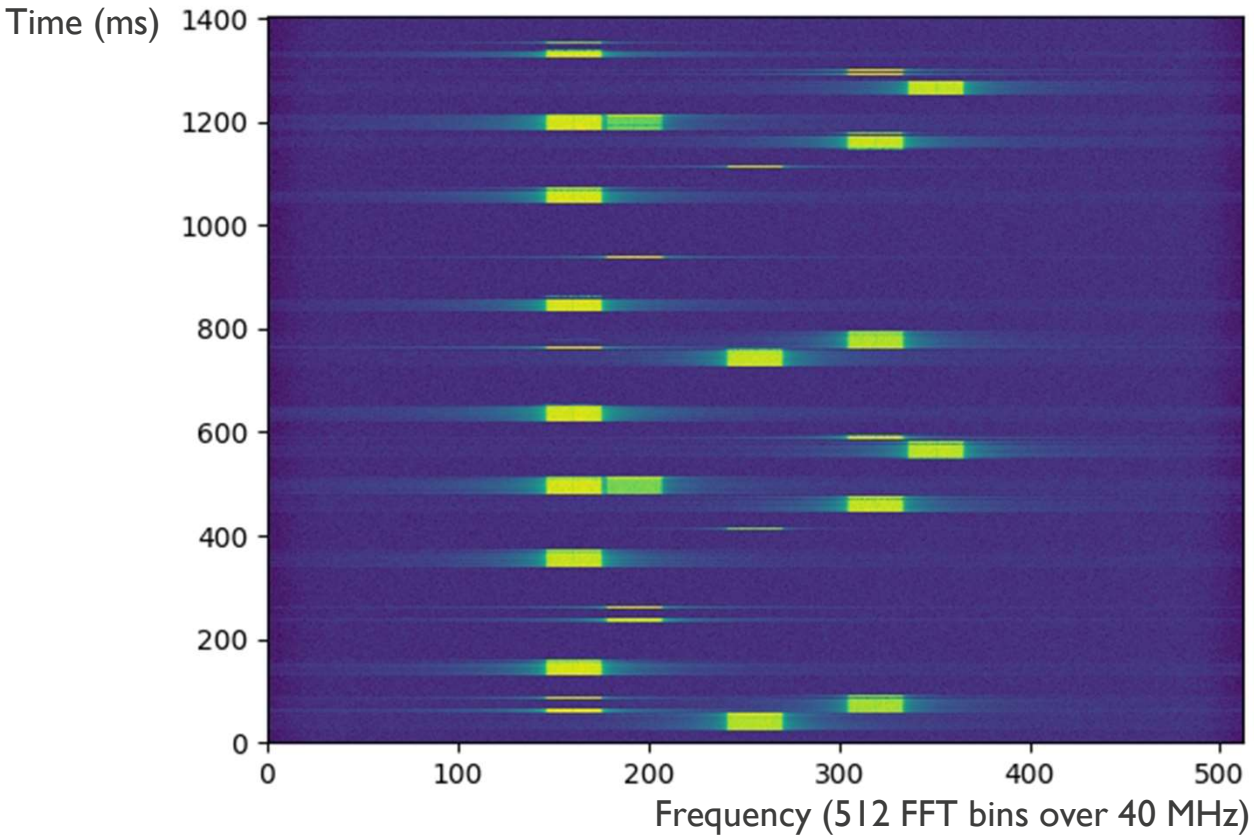
Channel



Time (timeslots 20ms)

DARPA - SECOND SPECTRUM COLLABORATION CHALLENGE

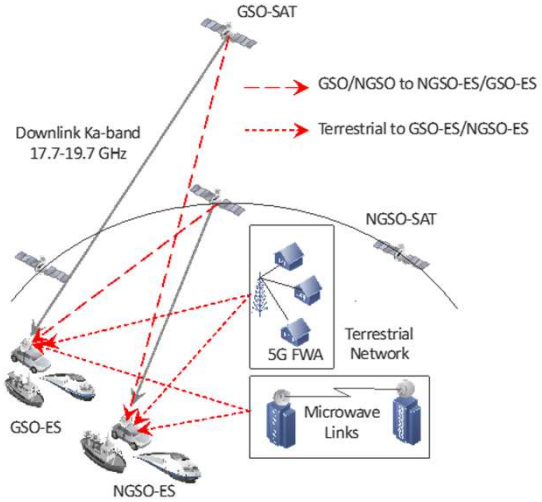
ACTIVE INCUMBENT REAL TIME DETECTION AND AVOIDANCE

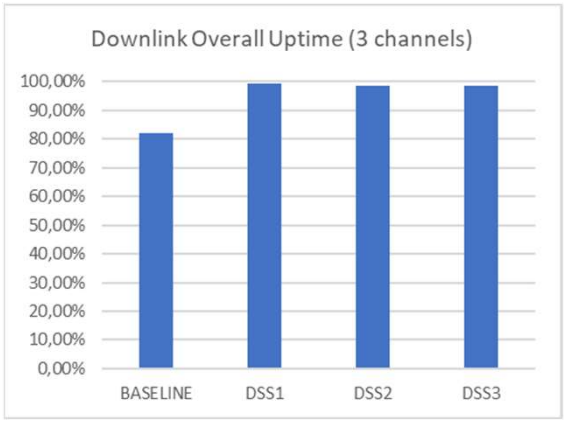


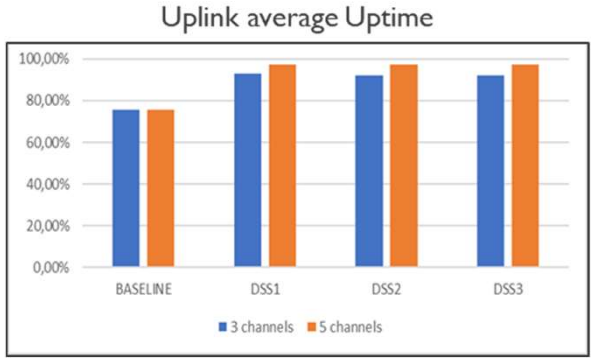
IMEC ACHIEVEMENTS

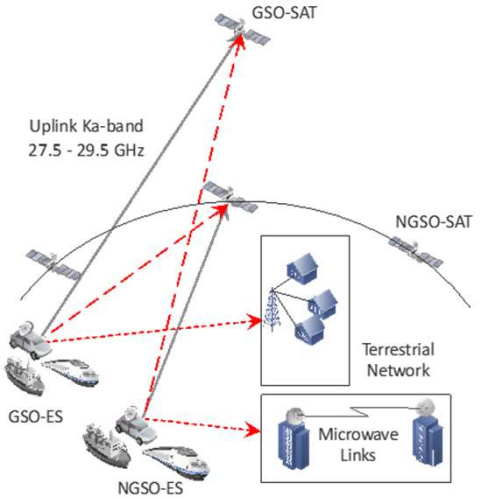
ESA CODYSUN

- 3 major techniques were tested
  - Spectrum sensing (uncoordinated)
  - Collaboration protocol (decentralized coordinated)
  - Hybrid solution (both 1 and 2 active)
- Results proven that many different cases of interference can be mitigated (inline interference, side and back-lobe interference, adjacent channel interference)
- Uptime of links in any case is significantly improved









See for more details: https://www.mdpi.com/1424-8220/21/23/8052

TAKE AWAY MESSAGE

Fixed spectrum assignment is not sustainable

General points

- ***Migration path needed towards dynamic shared spectrum***
- ***We need to promote efficient spectrum usage***
- ***Rx (ground truth) is way more important than Tx (model)***
- ***Harmonization of spectrum sharing rules is needed across national borders and segments***
  - ***Standardization on PHY agnostic DSS approaches is needed (enabling cross-technology application)***
  - ***Would allow for defining DSS enforcement policies***

Next possible steps

- Move from theoretical/simulation studies to deploying experimental PoCs
- Urgent need for defining a regulated DSS band for experimentation/verification of theoretical findings
- Comparison of centralised versus distributed DSS approaches is needed

"Many good ideas do not end in a working solution"
(Paul Tilghman - DARPA SC2)

embracing a better life