October 2023

C-Vehicle to Everything (V2X)

Punit Rathod

V2X is a critical component to safety

Giving vehicles the ability to communicate with each other and beyond

Vehicle-to-infrastructure (V2I)

e.g. traffic signal timing / priority

Vehicle-to-network (V2N)

e.g. real-time traffic / routing, cloud services

Vehicle-to-vehicle (V2V)

e.g. collision avoidance safety systems

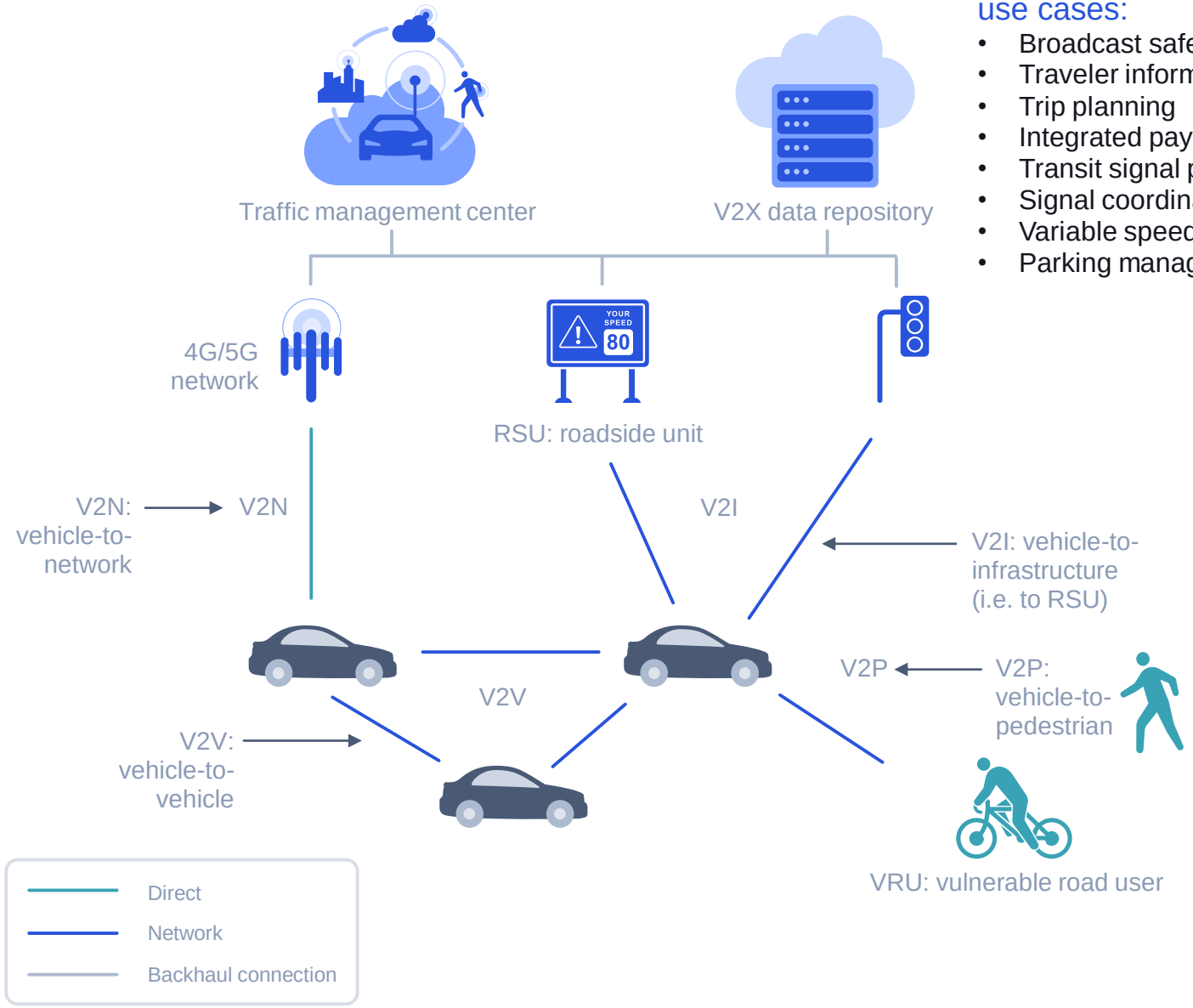
Vehicle-to-pedestrian (V2P)

e.g. safety alerts to pedestrians, bicyclists

Enhanced range and reliability for direct communication without network assistance

C-V2X architecture

C-V2X allows vehicles to communicate directly with each other, roadside infrastructure and other road users



Potential data driven use cases:

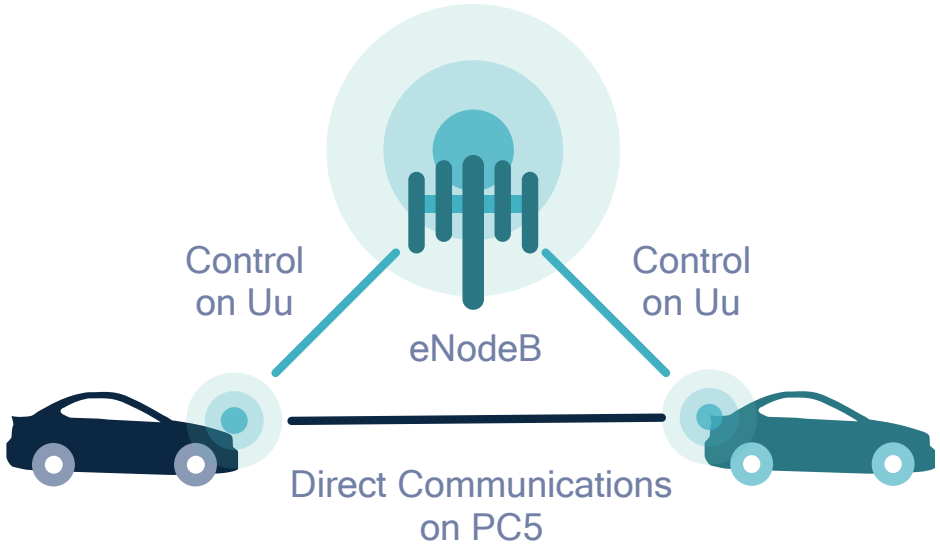
- Broadcast safety alerts
- Traveler information
- Trip planning
- Integrated payment
- Transit signal priority
- Signal coordination
- Variable speed limit signs
- Parking management

C-V2X Direct Communication defines two modes of operation*

Mode 3

- eNodeB schedules PC5 resources
- Relies on eNodeB for timing
- USIM-based operation

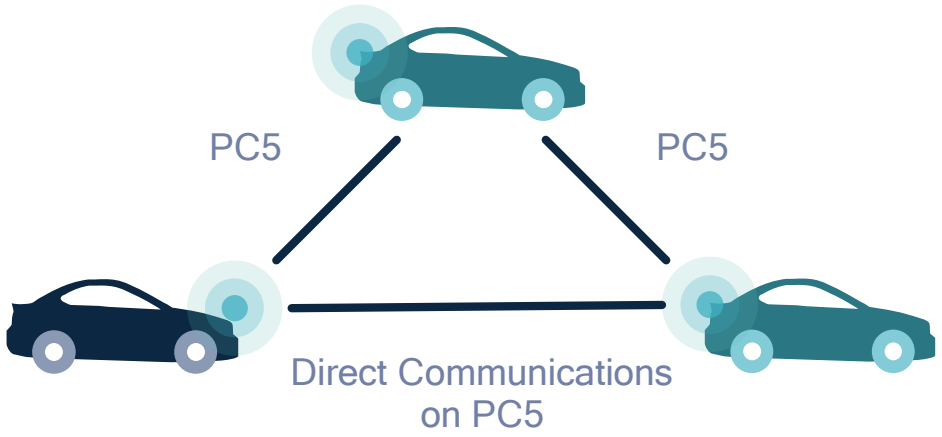
Network-managed



Mode 4

- Distributed/autonomous scheduling
- GNSS is the primary source of timing
- USIM-less operation

Self-managed

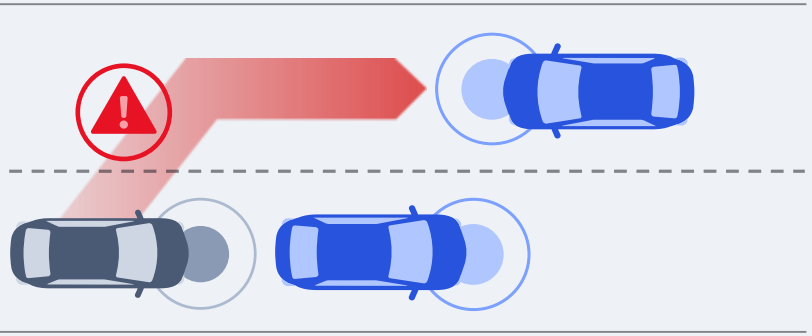


(via PC5 interface on 5.9GHz)

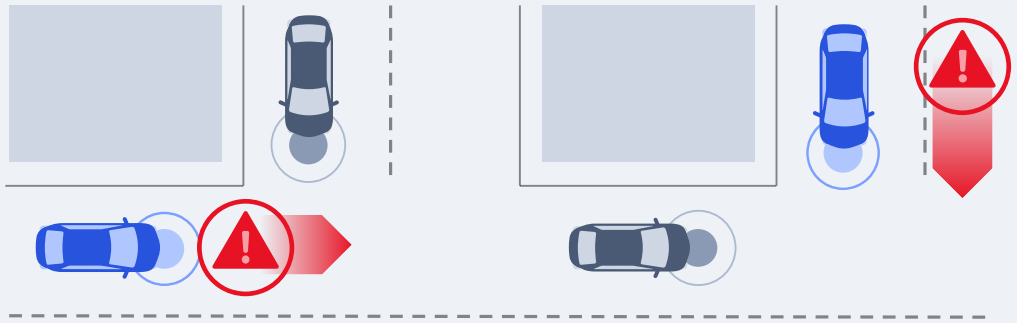
* Mode 1&2 are for R-12/13 D2D comm. design which does not scale for high speeds and high density. Mode 3&4 are for V2X comm. that was designed during R-14.

Vehicle-to-vehicle

Do not pass warning (DNPW)

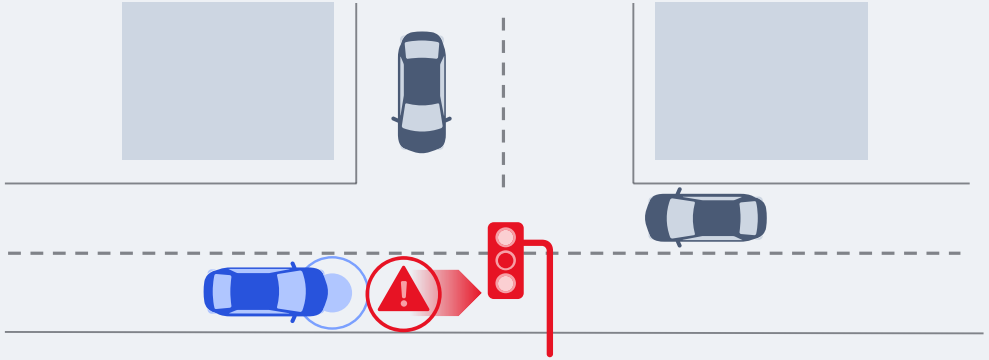


Intersection movement assist (IMA) at a blind intersection

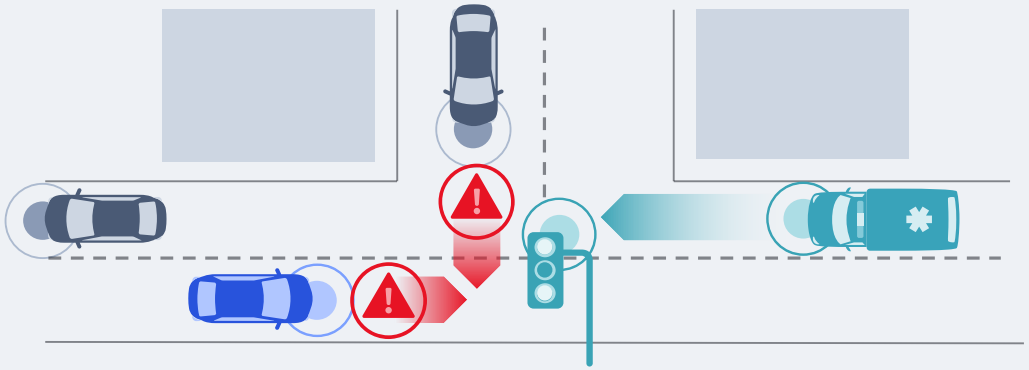


Vehicle-to-infrastructure

Red light violation warning (RLVW)

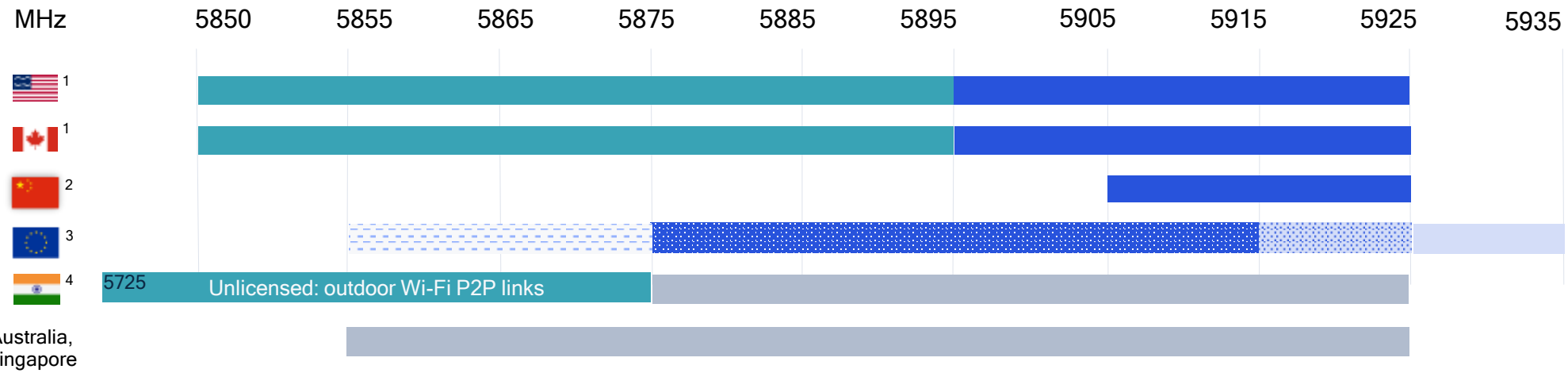


Emergency vehicle pre-emption



Day 1 C-V2X use cases can significantly enhance safety

Global snapshot of allocated/targeted ITS spectrum



Korea, Australia, Brazil, Singapore

IND 29 (NFAP 2022)
Subject to not constraining the use of the frequency band 5 875 to 5 925 MHz by the services to which it has been allocated in the RR, the band may also be considered for V2X technologies/Intelligent Transport Systems.

Unlicensed
C-V2X
ITS safety
ITS non-safety shared with short-range devices (SRD)
ITS
Urban rail
ITS safety (conditional on protection for urban rail)

1 FCC (USA) and ISED (Canada) assigned upper 30 MHz of ITS band (5.895-5.925 GHz, B47).
2 MIIT officially regulated the upper 20 MHz (5.905-5.925 GHz), Likely to allocate additional spectrum in the future.
3 ITS spectrum allocation in Europe is still pending. The EU has adopted technology neutrality in spectrum allocation.
4 National Frequency Allocation Plan 2022 allows for V2X / ITS usage

ITS spectrum: India

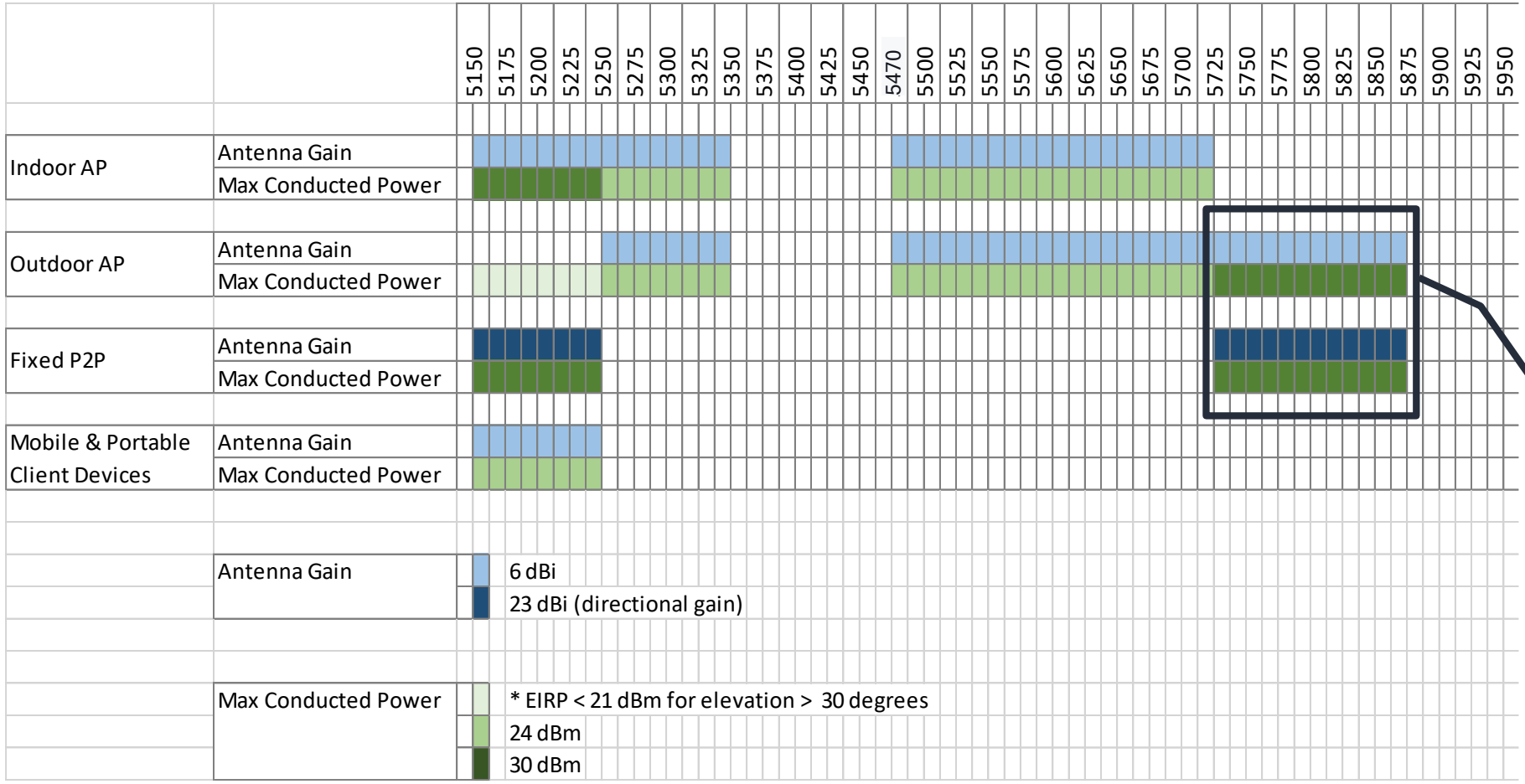
IND 29 (NFAP 2022)
Subject to not constraining the use of the frequency band 5 875 to 5 925 MHz by the services to which it has been allocated in the RR, the band may also be considered for V2X technologies/Intelligent Transport Systems.

Lessons learned – best scenario for current (basic safety) and future (advanced safety) use cases is as much spectrum as possible.

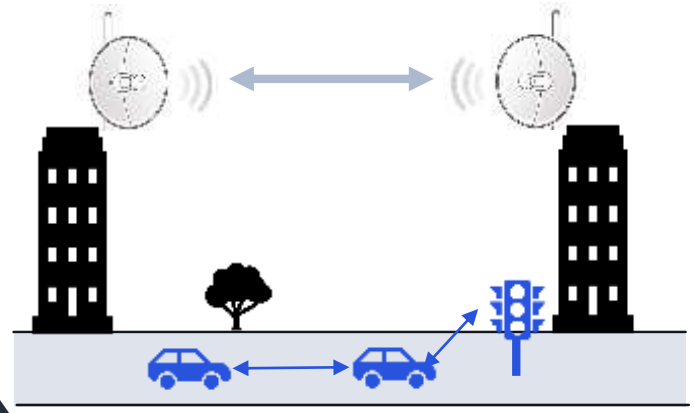
See grey bar for Asian countries and Brazil.

5 GHz spectrum in India

- As per GSR 1048 (E) dt. 18 October 2018



Typical Deployments in 5725 – 5825 MHz



Outdoor AP
- 6 dBi antenna
- 30 dBm max conducted power

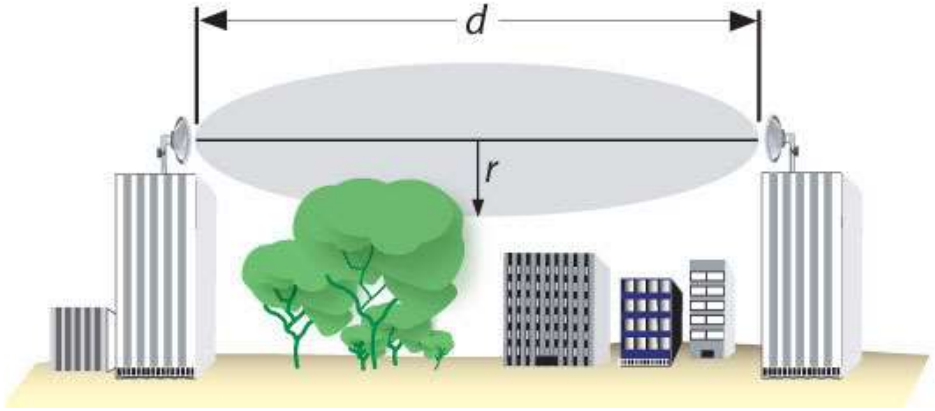
Fixed P2P Links
- 23 dBi directional gain antenna
- 30 dBm max conducted power

Co-existence Test results

- Test results show that interference level should be < -110 dBm/MHz to protect C-V2X

OOBE from Wi-Fi	Minimum Isolation needed for no-impact to C-V2X
-17 dBm / MHz	> 93 dB
-27 dBm / MHz	> 83 dB

- Typical Installation of outdoor P2P links



- Typical outdoor P2P installation at rooftop height to avoid obstacles in Fresnel zone.
- Height ensures separation
- Translating to sufficient RF isolation

Outdoor and P2P links pose no threat to C-V2X

Satellite Uses in 5.9 GHz band

As per discussion with stakeholders

- GSO Satellite, Earth-to-Space links
  - TT&C in a few satellites
  - Feeder links to S-MSS payloads
  - Elevation: 83 degree
  - Altitude > 36,000 km
  - Earth Station Locations: 2-3 known locations

ECC Report 101

EXECUTIVE SUMMARY

In response to a request from ETSI for the designation of spectrum for Intelligent Transport Systems (ITS) around 5.8 GHz, the compatibility studies were conducted between these systems and the existing users.

It was decided to conduct compatibility studies between ITS in general and the following services/systems:

1) Fixed Satellite (E-s) Service,
2) Radiolocation service
3) Non-Specific Short-Range Devices (SRD) introduced in accordance with the Recommendation 70-03,
4) Fixed Wireless Access (FWA) devices
5) Fixed service (above 5925 MHz)
6) Radio amateur (below 5850 MHz)
7) RTTT below 5815 MHz

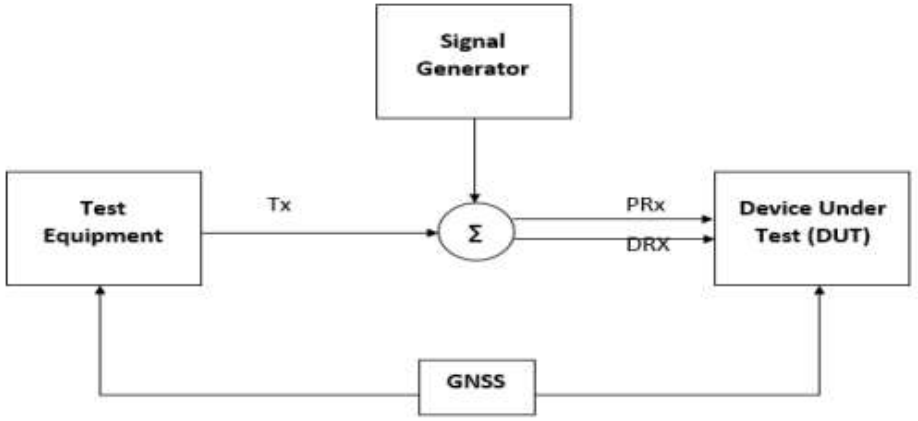
The report has been completed for the compatibility studies in the band 5855-5925 MHz and the following table shows the conditions under which sharing would be feasible:

Services and applications	Section of this report	ITS as interferer	ITS as victim
Radio Amateur	3.1	Compatibility is achieved.	Compatibility is achieved.
FSS	3.2	Compatibility is achieved.	Compatibility achieved in most cases taking into account the limited number of earth stations and real terrain shielding.

- No challenges to Satellite usage in India from ITS deployments
- No impact on ITS from FSS Earth Stations

Adjacent Channel Selectivity and In Band Blocking

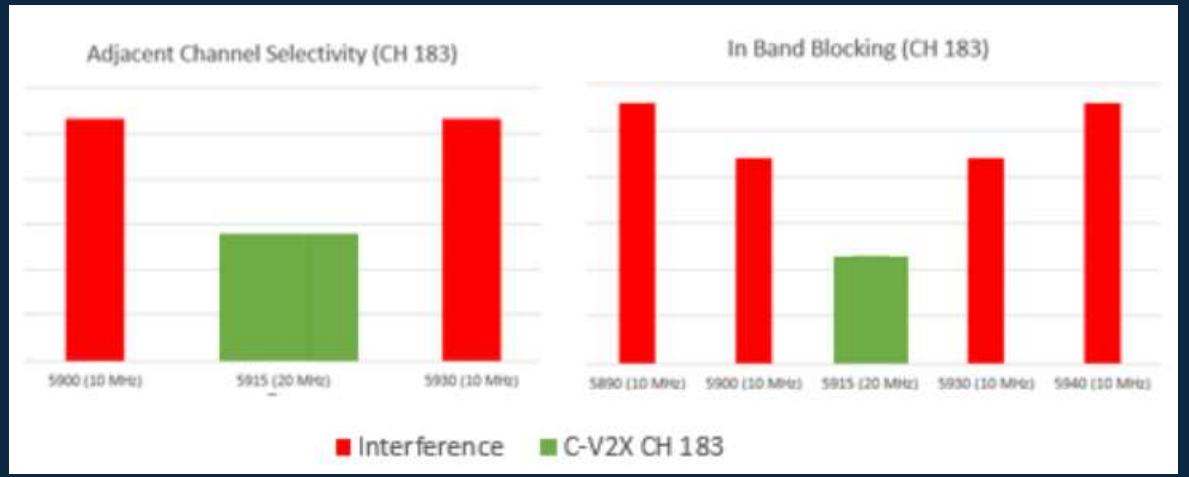
- Adjacent Channel Selectivity (ACS)
  - tests the OBU's ability to receive data, in the presence of an adjacent channel signal at a given frequency offset from the center frequency of the assigned channel, under conditions of ideal propagation and no added noise
- In Band Blocking:
  - tests the OBU's ability to receive data, in the presence of an in-band interfering signal at +/-15 MHz and +/-25 MHz offset from the center frequency of the assigned channel, under conditions of ideal propagation and no added noise



Observations

Results Summary

- ACS Result: Pass
- In Band Blocking Result: Pass
- Testing performed as per 3GPP 36.521-1
  - Test case 7.5G.1 & 7.6.1G1



NFAP 2022

Published in October 2022

- NFAP revision to be unambiguous and ensure ecosystem growth and promote interoperability
- IND 29

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Harmonized ecosystem to foster ecosystem growth and enable interoperability

Global ITU-R Developments Standards

- ITU-R
  - M.2520: The use of the terrestrial component of International Mobile Telecommunications for the Cellular-Vehicle-to-Everything, Oct 2023
  - draft new Report ITU-R M.[CAV] - Connected Automated Vehicles

- APT
  - AWG REP-121: APT Report on cellular based V2X for ITS applications in APT countries

Spectrum situation with Focus on Safety, Efficiency

- Need to ensure
  - dedicated spectrum for ITS
  - access to the spectrum without any cost because several of the use-cases are directly impacting safety of life (e.g., collision warning, emergency vehicle alert, etc.)
- Strong opportunity for India to lead because it is not limited by installed base of legacy systems
  - No legacy deployments
  - Significant unique position (e.g., density of traffic, absence of trams, two and three-wheeler density, etc.)
- Avoid fragmentation of spectrum to avoid technology islands
  - Incompatible technology options at PHY layer
  - Interoperability very important
    - Unified technology ensures all players in the ecosystem can communicate with each other (e.g., both large players and start-ups in automotive space can be on same technology platform) ensuring safer roads.

Thank you

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