CEPT ECC
Electronic Communications Committee

ECC Report 373

Exploring the regulatory and technical elements with respect to national authorisation of satellite based Direct-to-Device (D2D) communications via existing available smartphones

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0 EXECUTIVE SUMMARY

This Report addresses the regulatory and technical aspects of satellite-based Direct-to-Device (D2D) communications using smartphones already placed on the market up until mid-2023 (including 3GPP NTN in the Mobile-Satellite Service (MSS) bands and/or connectivity in MFCN bands). D2D services are designed to extend mobile connectivity to underserved or remote areas by enabling smartphones to connect directly to satellites, either in MSS or MFCN frequency bands.

The D2D service via satellite towards unmodified cellular devices is already available, in some countries, and the first systems are already operational.

Two main approaches are identified:

- D2D-MSS: operation in spectrum already allocated to the MSS. This approach benefits from a well-established international and European regulatory framework. In CEPT countries, MSS networks are generally authorised under harmonised rules, and user terminals are often exempted from individual licensing. D2D-MSS can therefore be deployed today without the need for new regulatory measures, as long as the deployment complies with the conditions of existing frameworks, while ensuring coexistence with incumbent services through existing International Telecommunication Union (ITU) and CEPT mechanisms;
- D2D-IMT: operation in spectrum allocated to the Mobile Service (MFCN/IMT bands). This approach requires partnerships between Mobile Network Operators (MNOs) and Satellite Network Operators (SNOs). D2D-IMT faces important regulatory challenges: the current MFCN authorisations only authorise terrestrial use; ITU Radio Regulations (RR) provide no prior protection mechanisms (assignments are typically made under RR No. **4.4**); technical conditions and limits to protect MFCN and other services are not yet defined. Section 4 defines other issues such as cross-border interference, market access, and enforcement issues which remain unresolved.

Main findings:

- The existing MSS framework is ready to accommodate compliant D2D-MSS without regulatory changes;
- D2D-IMT requires further regulatory development at both national and European levels, including potential adjustments to licensing conditions and harmonised measures;
- Studies are needed on coexistence of D2D-IMT with MFCN and adjacent band services, as well as on cross-border coordination mechanisms;
- Preparations towards ITU-R World Radiocommunication Conference 2027 (WRC-27) Agenda Item 1.13 will be central to addressing long-term regulatory solutions for D2D-IMT.

The European Commission (EC) has issued the Mandate to the CEPT on Complementary satellite Direct-to-Device (D2D-IMT) connectivity in terrestrial European Union (EU) harmonised frequency bands to CEPT. This Mandate addresses feasibility, coexistence and compatibility studies for the use of relevant EU-harmonised bands, originally designed for terrestrial wireless systems providing ECS, by satellite systems providing complementary D2D-IMT connectivity. It aims to ensure the protection of existing uses, including their evolution and development, within these bands and adjacent ones, both across Member States' borders and at the EU's external border. It further addresses the development of EU-harmonised technical conditions. Further work in CEPT is anticipated in response to this mandate.

D2D has the potential to enhance connectivity by complementing terrestrial mobile networks coverage, providing societal benefits such as improved coverage, resilience, and support for emergency services. While compliant D2D-MSS can be implemented within the current regulatory framework, the deployment of D2D-IMT requires significant further work. CEPT administrations will also need to exchange information, study technical compatibility, and develop harmonised ECC approaches to ensure that D2D-IMT services can evolve while protecting existing users of spectrum.

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LIST OF ABBREVIATIONS

Abbreviation	Explanation
3GPP	3rd Generation Partnership Project
5GNR	5G New Radio
AAS	Active Antenna Systems
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
AI	Agenda Item
AML	Advanced Mobile Location
ATC	Air Traffic Control
BR	Radiocommunication Bureau
BS	Base Station
CGC	Complementary Ground Component
D2D	Direct-to-device
D2D-IMT	Direct-to-device IMT
DL	Downlink
DME	Distance Measuring Equipment
EC	European Commission
ECC	Electronic Communications Committee
ECS	Electronic Communications Services
EECC	European Electronic Communications Code
EFIS	ECO Frequency Information System
e.i.r.p.	Equivalent Isotropic Radiated Power
ETSI	European Telecommunications Standards Institute
EU	European Union
FDD	Frequency Division Duplexing
FDP	Fractional Degradation of Performance
FS	Fixed Service
FSS	Fixed-Satellite Service
GSMA	Global System for Mobile communications Association
GSM-R	Global System for Mobile Communications on Railways

Abbreviation	Explanation
GSO	Geostationary Orbit
GSOA	Global Satellite Operators Association
HIBS	High-altitude platform stations as International Mobile Telecommunications Base Stations
HPBW	Half Power Beam Width
IMT	International Mobile Telecommunications
IoT	Internet of Things
IPX	IP Exchange
ITU	International Telecommunication Union
ITU-R	International Telecommunication Union Radiocommunication Section
LEO	Low Earth orbit
LPD-S	Low Power Devices Communicating with Satellites
LSA	Licensed Shared Access
LTE	Long Term Evolution
MEO	Medium Earth orbit
MFCN	Mobile/Fixed Communications Networks
MNO	Mobile Network Operator
MS	Mobile Service
MSS	Mobile Satellite Service
MSSA	Mobile Satellite Services Association
NGSO	Non-Geostationary Orbit
NIB	Non-Interference Basis
NPB	Non-Protection Basis
NPRM	Notice of Proposed Rule Making
NTN	Non-terrestrial Networks
PFD	Power Flux Density
PLMN	Public Land Mobile Network
PSAP	Public Safety Answering Point
QoS	Quality of Service
RA	Radio Access
RAS	Radio Astronomy
RAN	Radio Access Network
RF	Radio Frequency
RMR	Railway Mobile Radio

Abbreviation	Explanation
RR	Radio Regulations
RSPG	Radio Spectrum Policy Group
SCS	Supplemental Coverage from Space
SDL	Supplemental Downlink
SN	Satellite Network
SNO	Satellite Network Operator
S-PCS	Satellite Personal Communications Services
TDD	Time Division Duplexing
TN	Terrestrial Network
TRA	Terrestrial Radio Access
UE	User Equipment
UL	Uplink
WARC	World Administrative Radio Conference
WRC	World Radiocommunication Conference

1 INTRODUCTION

1.1 BACKGROUND TO THE REPORT

In the context of this Report, D2D communications are meant to provide satellite-based connectivity to smartphones already placed in the market up until mid-2023 (including connectivity using MSS bands and/or MFCN bands). D2D communication is expected to provide additional coverage particularly in underserved areas. The D2D satellites in this Report can be either geostationary orbit (GSO) or non-geostationary orbit (NGSO) satellites.

With the growth in demand for seamless connectivity, particularly in remote or underserved regions, satellite networks may offer supplementary coverage across vast expanses of land and sea, filling in the gaps where terrestrial infrastructure falls short.

Existing MSS networks and systems that operate in bands already allocated to MSS in the Radio Regulations (RR) on a primary basis and licensed by administrations for MSS use, including in the L-band and S-band, can communicate seamlessly with terrestrial mobile handsets/existing smartphones.

In addition, some satellite operators are considering providing D2D services in the spectrum allocated to the terrestrial MS that does not have a corresponding MSS allocation, seeking authorisations from individual CEPT administrations.

1.2 DIFFERENT OPTIONS OF D2D

Two different spectrum approaches for the provision of D2D communications are being considered:

- D2D-MSS: the use of spectrum allocated to MSS and assigned to satellite network operators (SNO);
- D2D-IMT: the use of spectrum allocated to MS and assigned to mobile network operators (MNO).

This Report describes the two approaches and their associated regulatory and technical considerations to provide regulators with additional clarity when making decisions. The Report contains a regulatory analysis of issues linked with national authorisation of D2D, to avoid the risk of interference to other systems and services, including but not limited to cross-border interference. There is a need to develop a common understanding of the regulatory and technical elements that are required to be addressed.

D2D-MSS solutions are being deployed either by integrating proprietary MSS technology directly into the smartphone, or through the implementation of 5G New Radio (5GNR) standard enhancements for non-terrestrial networks (NTN). The main differences are summarised in Figure 1.

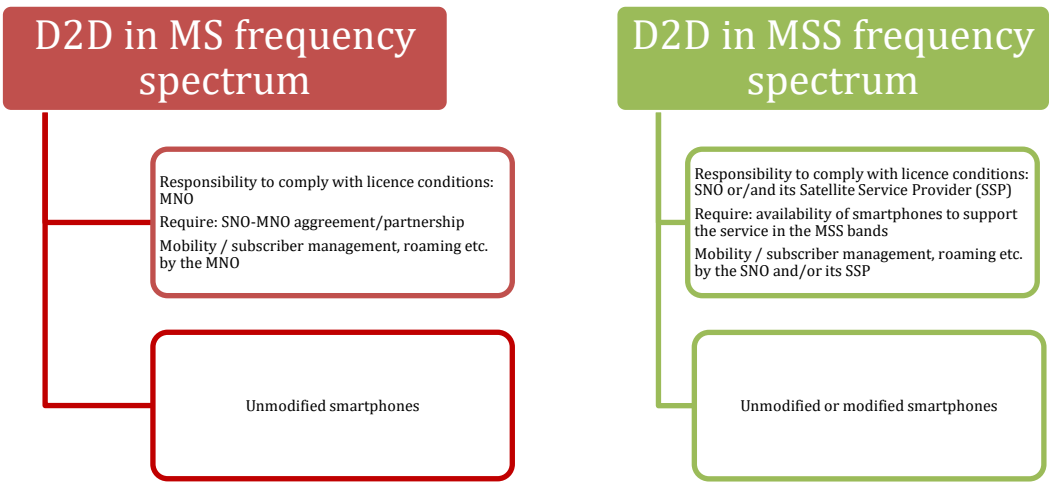

Figure 1: General overview on D2D alternative solutions

1.3 OBJECTIVE OF THE REPORT

The aim of this Report is to explore the regulatory and technical elements with respect to national authorisation of satellite based D2D communications via existing available smartphones.

This Report develops an understanding of national D2D satellite connectivity (technical description of the satellite component and how it works), where some systems could operate in the absence of a framework providing international recognition and protection. It also explores national authorisation and technical interference issues in the current spectrum usage regulatory framework. The "existing available smartphone" in this Report are unmodified cellular devices already placed on the market up until mid-2023 (including 3GPP NTN in MSS bands and/or connectivity in MFCN bands).

This Report mainly focuses on satellite-to-cellular device systems operating in frequency bands without satellite allocations (i.e. MFCN bands).

2 D2D USING MSS FREQUENCY BANDS

2.1 SYSTEM DESCRIPTION

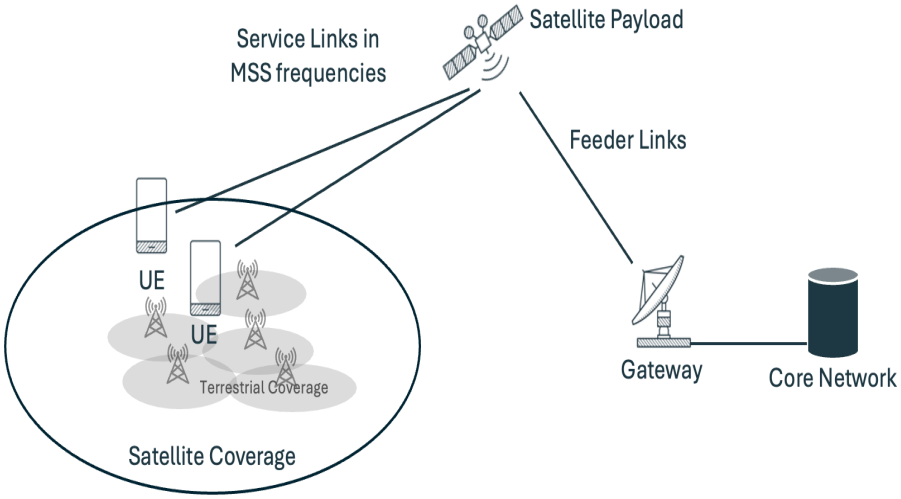

Figure 2: Illustration of D2D-MSS

D2D-MSS is an application of MSS that leverages satellite infrastructure of satellite systems/networks operating in MSS spectrum as shown on Figure 2. D2D-MSS can support network coverage over the sea and land where terrestrial coverage is not feasible. The satellite payload can be "transparent" to the radio protocol, or regenerative, with on board network functions. In case of transparent payload, the satellite forwards the radio protocol received from the UE (via the Service link in MSS frequencies) to the gateway (via the feeder link in frequencies allocated to space services) and vice-versa. The transparent payload changes the carrier frequency of the received uplink UE signal, filters and amplifies it before transmitting it on the feeder link and vice-versa, i.e. the satellite corresponds to an analogue RF repeater. A regenerative payload on top of RF filtering, frequency conversion and amplification also has on-board processing capabilities (for demodulation/decoding, switching and/or routing, coding/modulation). Regenerative payloads can also enable inter-satellite links or on-board edge computing capabilities.

The Core Network can belong to either the SNO or an MNO. For example, in 3GPP Release 17 for a transparent payload a base station can be emulated at the end of the feeder link and connected to an MNO 5G Core Network, which in turn is connected to the Public Network. For a regenerative payload, base station and even part of the 5G core network functions can be performed on board the satellite. More information is available in ETSI TS 138 300 [29].

Due to the fact that terrestrial and satellite networks use different frequency bands, it is possible to operate terrestrial and satellite coverage concurrently, in the same geographic areas, without mutual harmful interference. Therefore, D2D-MSS has the flexibility to close terrestrial coverage gaps (overlapping without the need for separation distances) or provide services if terrestrial networks experience an outage. Coverage can be extended without impacting terrestrial networks' capacity and MNO's capability to extend terrestrial coverage using IMT frequencies. Information of specific D2D-MSS systems is provided in Annex 1.

The UE used in such system are smartphones which are capable of operating in MSS frequency bands (see examples in Annex 1). Some of the commercial phones on the market for general terrestrial cellular service are compatible with 3GPP NTN and integrate NTN capabilities in MSS spectrum. Such capabilities are not specific to the SNO nor a specific phone manufacturer, thus ensuring interoperability. The RF parameters of the smartphones being identical in TN or NTN modes, the satellite segment has to provide sufficient performances (including large satellite antenna) to enable the link budget and throughput. D2D-MSS solutions are also being deployed which integrate proprietary MSS technology directly into the smartphone, providing D2D capability, but not based on the 3GPP NTN waveform.

2.2 MSS FREQUENCY BANDS

Satellite operators provide direct to device service in globally allocated ITU MSS bands. Starting at World Administrative Radio Conference 1992 (WARC-92), the L-band and S-band were internationally harmonised and allocated for MSS including the satellite component of IMT.

The following bands in Table 1 with existing MSS allocations have been specified for possible communications between smartphones and satellites in 3GPP standards by mid-2023 and it was noted that D2D-MSS solutions are also being deployed that integrate proprietary MSS technology directly into the smartphone, providing D2D capability.

Table 1: Bands specified for possible communications between smartphones and satellites in 3GPP standards by mid-2023

Frequency Bands		
Uplink (UL)	**Downlink (DL)**	**Duplex**
1980-2010 MHz	2170-2200 MHz	FDD
1626.5-1660.5 MHz	1525-1559 MHz	FDD
1610-1626.5 MHz	2483.5-2500 MHz	FDD[1]

2.3 TECHNICAL CONSIDERATIONS

For the use of MSS bands, the L-band and S-band have long been allocated to the MSS in the Radio Regulations (RR). The studies have been carried out within regulatory international fora to address regulatory, technical, and operational considerations for MSS services in these allocated bands and these studies are well established and still apply. Coexistence and sharing mechanisms have been established in the RR and updated as the needs of the mobile satellite service have evolved. In addition, specific coexistence issues have been addressed or are being addressed in the work under certain RR Resolutions and Recommendations, for example:

- Recommendation 206 (Rev.WRC-23) [32]: Studies on the possible use of integrated mobile-satellite service and ground component systems in the frequency bands 1525-1544 MHz, 1545-1559 MHz, 1626.5-1645.5 MHz and 1646.5-1660.5 MHz;
- Resolution 225 (Rev.WRC-23) [39]: Use of additional frequency bands for the satellite component of IMT;
- Resolution 716 (Rev.WRC-23) [41]: Use of the frequency bands 1980-2010 MHz and 2170-2200 MHz in all three Regions and 2010-2025 MHz and 2160-2170 MHz in Region 2 by the fixed and mobile satellite services and associated transition arrangement.

The MSS bands are satellite communications resources, with sharing mechanisms established through the ITU satellite coordination and notification procedures, i.e., RR Articles **9** and **11**, licensing procedures, and the corresponding national allocations and authorisations. The regulatory environment for MSS in the L- and S-bands is established, implemented and has supported traditional MSS operations using satellite handheld devices.

2.3.1 Global limits (e.g. PFD) and coordination trigger levels

D2D using MSS frequency bands, as any other MSS application, falls in the regulatory category of satellite networks/systems subject to coordination, for which the following process of the RR applies:

- Procedures: RR Articles **9** and **11**;
- Submission Format: RR Appendix **4**;
- Technical and Operational Limits: RR Articles **5**, **21**, **22**, etc.

[1] The band 1610-1626.5 MHz and 2483.5-2500 MHz were ultimately specified in 3GG Release 18 approved in June 2024 (band n°254)

- Criteria and Methods to Identify Coordination Requirements: RR Appendices **5**, **7** and **8**.

PFD thresholds in RR Appendix **5** are for determining the need for a coordination with terrestrial services. Table 2 provides example threshold values of PFD from MSS space stations for angles of arrival higher than 25 degrees that are derived based on methodology of RR Appendix **5**.

Table 2: Extracts from RR Appendix 5: Thresholds value from Table 5-2 of power flux-density from MSS space stations in the 1-3 GHz for Region 1

Frequency band	PFD coordination threshold values	Remarks
1518-1525 MHz	-118 dBW/m²/MHz for 25° < ε ≤ 90° (for NGSO and GSO space station)	Additional decision criteria is the % of FDP
2160-2200 MHz	-113 dBW/m²/MHz for 25° < ε ≤ 90° (for NGSO space station) --118 dBW/m²/MHz for 25° < ε ≤ 90° (for GSO space station)	Not applicable to IMT in 2170-2200 MHz, as terrestrial and satellite components are not intended to operate in the same area or on common frequencies
2483.5-2500 MHz	-111.5 dBW/m²/MHz for 25° < ε ≤ 90° (for NGSO space station) -118 dBW/m²/MHz for 25° < ε ≤ 90° (for GSO space station)	Values are based on Note 9 of Table 5-2 which applies in most CEPT countries

Other coordination thresholds values are also specified in RR Appendix **5** Table 5-2 which apply for angles of arrival less than 25 degrees, for coordination with analogue FS telephony, and other special cases as listed in the footnotes.

The implementation of MSS, including D2D-MSS, in the above listed frequency bands may require coordination in advance. In Europe, CEPT and the EU have developed harmonisation measures for MSS in these bands that eliminate potential service limitations resulting from the above mentioned pfd thresholds including complementary ground component [1], [4], [7], [9], [23], [26] and [29].

For protection of the radio astronomy service in certain adjacent bands and nearby frequencies, certain footnotes of the RR and Resolution 739 (Rev.WRC-19) apply (see Table 3). In addition, national requirements could vary between countries.

Table 3: Regulatory provisions for RAS protection from D2D-MSS

RAS frequency band	Existing MSS frequency bands	Remarks
1400-1427 MHz	1525-1559 MHz (space-to-Earth) (Res. 739 applies)	Primary RR No. **5.340**, RR No. **5.208B**
1610.6-1613.8 MHz	1525-1559 MHz (Res. 739 applies) 1610-1660.5 MHz (Earth-to-space) 1613.8-1626.5 MHz (space-to-Earth) (Secondary)	Primary RR No. **5.208B**
1660-1670 MHz	1668-1675 MHz (Earth-to-space)	Primary RR No. **5.376A**, RR No. **5.379C**
4950-4990 MHz	2483.5 MHz-2500 MHz (space-to-Earth)	RR No. **5.149**
4990-5000 MHz	2483.5 MHz-2500 MHz (space-to-Earth)	Primary RR No. **5.402**

2.4 REGULATORY FRAMEWORK IN EUROPE

The following EC and ECC Decisions and European Terminal Licensing Framework are applicable and relevant to the D2D-MSS connectivity:

a) EC Decision No 2007/98/EC [1] on the harmonised use of radio spectrum in the 2 GHz frequency bands for the implementation of systems providing MSS;

b) EC Decision 2009/449/EC [2] on the selection of operators of pan-European systems providing mobile satellite services (MSS);

c) EC Decision 2011/667/EU [3] on modalities for coordinated application of the rules on enforcement with regard to MSS;

d) ECC Decision (12)01 [9] (amended March 2022) on exemption from individual licensing and free circulation and use of satellite mobile terminals operating under the control of networks in the range 1 to 3 GHz;

e) ECC Decision (09)02 [7] (amended November 2012) on the harmonisation of the bands 1610-1626.5 MHz and 2483.5-2500 MHz for use by systems in the Mobile-Satellite Service;

f) ECC Decision (09)04 [8] on exemption from individual licensing and the free circulation and use of transmit-only mobile satellite terminals operating in the Mobile-Satellite Service allocations in the 1613.8-1626.5 MHz band;

g) ECTRA Decision (99)01 [14] on harmonisation of authorisation conditions in the field of Satellite personal Communications Services (S-PCS) in Europe, operating within the bands 1525-1544/1545-1559 MHz, 1626.5-1645.5/1646.5-1660.5 MHz;

h) ECC Decision (06)09 [4] on the designation of the bands 1980-2010 MHz and 2170-2200 MHz for use by systems in the Mobile-Satellite Service including those supplemented by a Complementary Ground Component (CGC);

i) ECC Decision (06)10 [5] on transition of terrestrial service operations from the Bands 1980-2010 MHz and 2170-2200 MHz in order to facilitate the Harmonised Introduction and Development of Systems in the mobile-satellite service including those supplemented by a Complementary Ground Component.

Additional relevant information may be found in the following documents:

- ECC Report 197 [23]: Compatibility studies – MSS terminals transmitting to a satellite in the band 1980-2010 MHz and adjacent channel UMTS services;
- ETSI TS 138 300 [29]: 5G; NR; NR and NG-RAN Overall description; Stage-2;
- Draft Harmonised Standard ETSI EN 304 122 [43]: NR-NTN (New Radio Non Terrestrial Networks) capable User Equipment operating in Frequency bands below 7,125 GHz; Harmonised Standard for access to radio spectrum;
- Draft Harmonised Standard ETSI EN 304 121 [44]: IoT-NTN (Internet of Things Non Terrestrial Networks) capable User Equipment operating in Frequency bands below 7,125 GHz; Harmonised Standard for access to radio spectrum.

2.4.1 Licence/Authorisation

The MSS spectrum has been allocated by the ITU and authorised at the national level by regulators from CEPT. A regulatory and technical framework has existed for decades and has been used for different applications.

The regulatory environment for these MSS bands is ready today to support the provision of new D2D applications.

The application of D2D-MSS is already possible in some countries without the need for new regulations as the current rules for provisioning MSS services can be used. In most countries, MSS services can be provided under a general authorisation when compliant with general authorisation conditions. It is noted that there are several ECC Decisions that established the harmonised use and exemption from individual licensing of different mobile earth stations.

A questionnaire confirmed that in CEPT countries the D2D-MSS terminals are exempt from individual licence. Some administrations mentioned that licencing of the other stations of the satellite system/network is required, which may in some cases include obligations on the satellite transmissions. Some other administrations mentioned that an individual authorisation for the full satellite network is required.

In some countries, the exemption of individual licence for terminals is performed through a general authorisation with obligations for the operator to register, in other countries the satellite operator needs an individual licence for the network that include an exemption of individual licences for the terminals of its customers. Most of the administrations require either a licence or registration of the service provider.

In general, administrations do not distinguish between national and foreign operators, but a limited number of administrations require operators to establish a company locally for sovereign issues.

2.4.2 Market access

The rules for D2D-MSS to access national markets differ between CEPT administrations where D2D-MSS terminals are exempt from individual licence. In some countries, a registration/general authorisation is applied while in other countries it is necessary to obtain an individual authorisation for the satellite network. It may differ between frequency bands in a country.

3 D2D USING MOBILE SERVICE FREQUENCY BANDS (MFCN/IMT BANDS)

3.1 SYSTEM DESCRIPTION

With D2D using mobile service frequency bands, agreements between the SNO and the MNO could resemble a roaming agreement (for SNO operating their own core network) or be more akin to a Radio Access Network service agreement (for SNOs not operating their core network). In this setup, the MNO manages both the spectrum resources and the customer relationship, while the SNO oversees its satellite network, which the MNO utilizes for D2D connectivity. The MNO enables the use of a part of its licensed spectrum to the SNO for this purpose, for example through a cooperation agreement. There are multiple agreements announced between MNOs and SNOs including certain European MNOs however there is no commercial offering that has started yet.

The core element of this approach is maintaining the MNO's responsibility for meeting the national licensing, regulatory and legal conditions for operating such a network. Under this approach, the satellite operator agrees to comply with applicable laws, regulations and spectrum licence requirements governing its provision of satellite operations using the MNO spectrum, including cross-border interference avoidance and incumbent service protections for in-band and out-of-band emissions.

The satellite can supplement the coverage of the MNO's terrestrial IMT network particularly in underserved areas. The MNO, as the spectrum licence holder, allows the satellite operator to utilise its spectrum to provide this extension of RF coverage consistent with its license terms.

The satellite payload can be "transparent" to the radio protocol, or regenerative, with on board network functions. In case of transparent payload, the satellite forwards the radio protocol received from the UE (via the Service link in MS frequencies) to the gateway (via the feeder link in frequencies allocated to space services) to the Base Station and vice-versa. The transparent payload changes the carrier frequency of the received uplink UE signal, filters and amplifies it before transmitting it on the feeder link and vice-versa, i.e. the satellite corresponds to an analogue RF repeater. A regenerative payload on top of RF filtering, frequency conversion and amplification also has on-board processing capabilities (for demodulation/decoding, switching and/or routing, coding/modulation).

Due to the nature of service and the potential interference effects, the MNO's frequency spectrum made available to the SNO should be agreed for D2D use in the intended coverage areas.

To explain and visualise the principle of MNO-SNO partnership, the example in Figure 3 has been used.

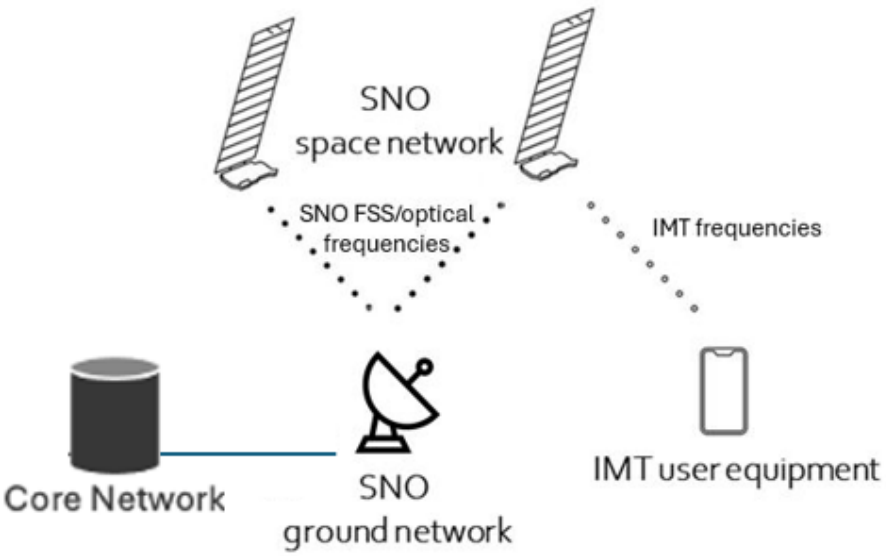

Figure 3: MNO-SNO partnership model

The satellite component is embedded into the MNO's network to provide a common network and subscriber management.

The user connections are routed via the Earth station gateway to the MNO's network access point. The MNO itself performs the subscriber management including end-to-end communications service and billing.

It should be noted that only the user link needs the specific treatment of spectrum assignments in the MS frequency ranges. The feeder links can be realised in other frequencies (e.g. Ku, Ka, Q/V) and/or via inter-satellite links.

3.2 MFCN FREQUENCY BANDS

The ITU-R World Radiocommunication Conference 2027 (WRC-27) has an agenda item (AI) 1.13 "to consider studies on possible new allocations to the mobile-satellite service for direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage, in accordance with Resolution 253 (WRC-23)" [40]. This Report deals only with the regulatory regime for national authorisation, which is not addressed by the WRC-27 AI 1.13. This Report proposes regulatory options that may be reviewed after the WRC-27.

The MFCN frequency division duplexing (FDD) bands harmonised in CEPT in the frequency range between 698 MHz and 2690 MHz are summarised in Table 4. The MFCN time division duplexing (TDD) bands and supplemental downlink (SDL) band harmonised in CEPT are given in Table 5 and Table 6.

The FDD bands in Table 4 are the frequency bands for potential D2D-IMT operation in Europe. For TDD bands, there are currently no known satellite operations providing D2D-IMT. Additional consideration is needed regarding the use for D2D-IMT usage because of technical issues.

FDD bands in Table 4, TDD bands in Table 5 and SDL bands in Table 6 are all TN MFCN bands to be protected in the same country and in the neighbour countries.

Table 4: FDD bands in Europe for potential D2D-IMT operations

Band	Downlink (MHz)	Uplink (MHz)
700 MHz	758-788	703-733
800 MHz	791-821	832-862
900 MHz	925-960	880-915
1.8 GHz	1805-1880	1710-1785
2 GHz	2110-2170	1920-1980
2.6 GHz	2620-2690	2500-2570

Table 5: TDD bands in Europe

Band	Downlink (MHz)	Uplink (MHz)
2.3 GHz	2300-2400	2300-2400
2.5 GHz	2570-2620	2570-2620
3.8 GHz	3400-3800	3400-3800

Table 6: SDL band in Europe

Band	Downlink (MHz)	Note
700 MHz	738-758	See ECC Decision (15)01 [10]
1.5 GHz	1427-1452 1452-1492 1492-1518	See ECC Decision (17)06 [11] See ECC Decision (13)03 [12] See ECC Decision (17)06 [11]
2.5 GHz	2570-2620	See ECC Decision (05)05 [13]

3.3 TECHNICAL CONSIDERATIONS FOR MFCN PROTECTION

The feasibility of providing D2D-IMT service is based on the use of a selected MFCN MS spectrum part (frequency block) per country or a defined area[2] within this country. This use of MS spectrum is based on the conditions from the authorisation of the partner MNO.

The provision of D2D-IMT is based on the agreed use by the SNO of a selected MFCN MS portion of the MNO licensed spectrum. This agreed use can be nationwide, provided that the MNO's spectrum usage rights conditions allow it, or limited to a defined area, depending on the agreement between the MNO and the SNO.

The dedicated use of the spectrum per defined area is needed because the user terminals have omnidirectional antennas and thus, any other satellites emissions, except from those satellites intended to communicate with, will create interference. This specific characteristic of the user equipment also requires attention to avoid self-interference from satellites beams of the same satellite constellation. MFCN networks are typically leveraging a frequency reuse of 1, and the technologies available to avoid inter-cell interference can be leveraged to avoid beam-to-beam interference.

Table 7 shows the various potential interference cases.

Table 7: Overview of wanted / unwanted emission types and interference mitigation and parameters considerations

Classifications of wanted and unwanted emissions	Frequency block for the D2D-IMT service	
	In-block	Out-of-block
Inside beam coverage	Wanted emissions inside beam coverage within the assigned frequency block	Unwanted emissions inside the beam coverage outside the assigned frequency block
	Subject for MNO-SNO partnership conditions	Technical licence conditions Parameters: out-of-block unwanted emissions and potential interference management techniques
Outside beam coverage	Emissions outside beam coverage towards neighbouring countries within the assigned frequency block	Unwanted emissions towards neighbouring countries outside the assigned frequency block
	Cross-border coordination with MNOs of neighbouring countries; Parameter: off-axis beam gain pattern of the satellite antenna and cross-border interference mitigation techniques	Cross-border coordination with MNOs of neighbouring countries and technical licence conditions; Parameters: out-of-block unwanted emissions and off-axis beam gain pattern of the satellite antenna and potential interference management techniques

[2] In Europe, the existing MS spectrum is typically licensed for the complete country.

The coexistence and sharing scenarios and the need for related studies will be considered in the following subchapters in more detail:

1 In-country D2D-IMT operations: The administration is responsible for the national authorisation towards the MNO-SNO partnerships and the possible attached specific D2D-IMT regulatory conditions to the national authorisation, but not for the system internal emissions / interference management.

2 In-country MFCN protection: Appropriate technical and regulatory measures are needed for the protection of the other incumbent MNOs from adjacent block interferences caused by the D2D-IMT satellite transmissions. Administrations will need to impose limits on unwanted emissions from D2D-IMT satellite transmissions into spectrum used by other MNOs.

3 Neighbouring countries MFCN protection: both in-block and out-of-block emissions could interfere with the MNOs networks and services in other countries. There is a need to define appropriate technical and regulatory measures, such as pfd limits and parameters to protect MFCN networks and services in other countries and for cooperation with the neighbouring Administrations to agree compliance. Also the notifying administration of the satellite system should be informed of the agreed levels.

For the uplink the situation remains rather unchanged compared to terrestrial networks: The system design of D2D satellite networks considers the typical standardised uplink e.i.r.p. of the market available smartphones (long term evolution (LTE) e.g. 200 mW), hence the situation of caused interference is the same as existing terrestrial networks. The above-mentioned need for dedicated spectrum per defined area is also needed. Sharing is not possible with terrestrial IMT or other mobile satellite terminals using the same uplink spectrum in the same area. This is in order to not create intra-system interference at the high gain receive antenna of the D2D satellite.

No existing limits and coordination triggers in RR Articles **21** and **22**, have been developed for protection of incumbent satellite and terrestrial services operating in specific MFCN frequency bands.

3.3.1 In-country D2D-IMT operations

From spectrum usage point of view, the D2D-IMT systems using MFCN frequency bands can be grouped into two types – both with the common basis of agreed frequencies for the satellite D2D emissions inside the area where D2D-IMT services are provided.

Type_A: The same frequency block can be used by both the IMT terrestrial network (TN) and the IMT Satellite Network (SN) with a needed geographical separation of the TN coverage zones and the Satellite D2D cells, as shown in Figure 4.

Type_B: Dedicated frequency block for D2D-IMT operations with national coverage, as shown in Figure 5.

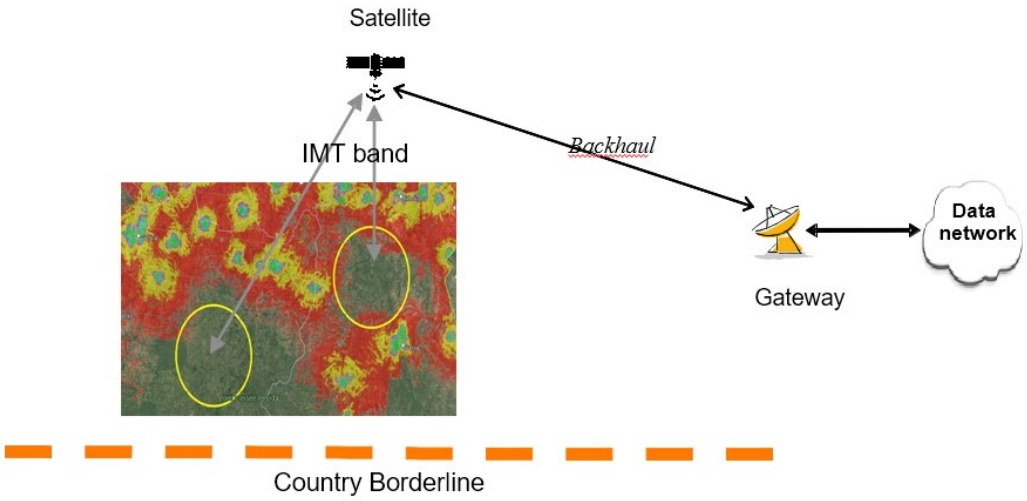

Figure 4: D2D-IMT with shared frequency block and separate coverage areas

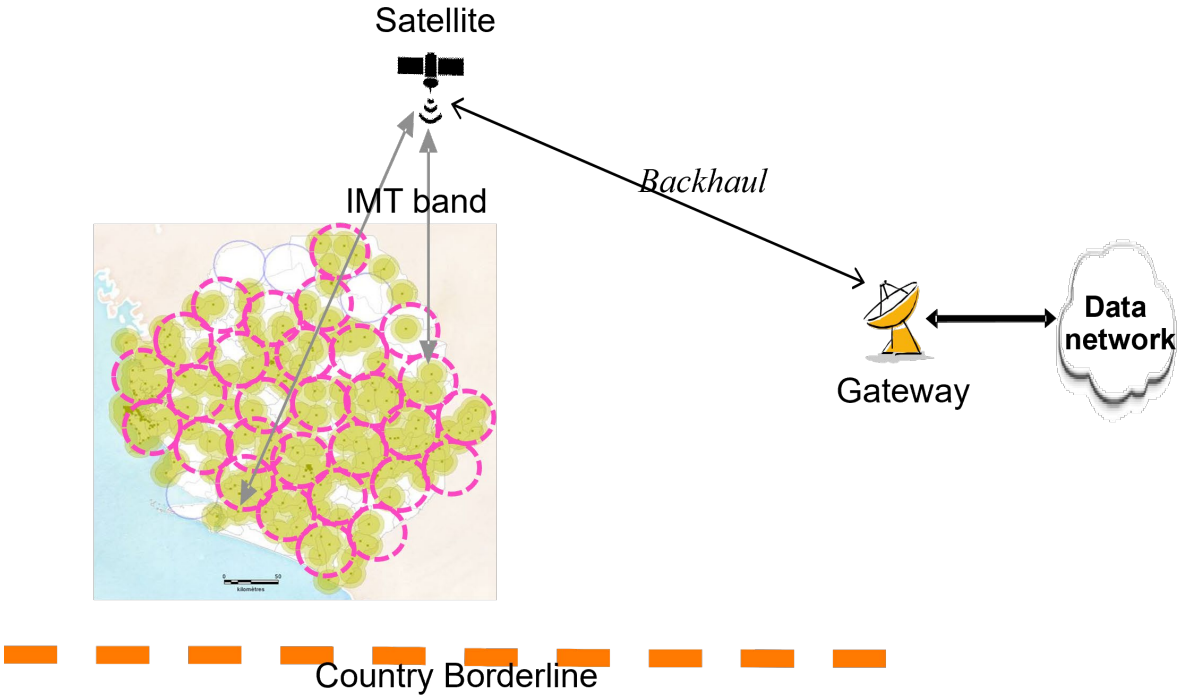

Figure 5: Dedicated frequency block for D2D-IMT with national coverage

Between the type_A and type_B D2D-IMT satellite operations, the frequency arrangement and coverage planning between SN and TN are different, but this is a subject of the satellite network operator (SNO) and mobile network operator (MNO) partnership, it is not a spectrum regulatory matter. The regulatory technical conditions need to take into account the protection of the other IMT TNs and other radio services within the same country (national or harmonised European spectrum regulation) and the IMT TNs and other radio services in the neighbouring countries (European/RR spectrum regulation).

As a consequence, there is a need for an MNO-SNO system compatibility including - inter alia – that:

- the partner MNO has to provide a suitable frequency block for the SNO which is not used by terrestrial system components in the same location;
- the SNO has to ensure that the aggregate interference it generates in the adjacent channel(s) is acceptable for terrestrial networks.

Under these conditions, following consequences are to be considered.

- in the uplink:
  - any potential interference towards MFCN systems will be managed by the partner MNO, noting that the UE transmit power levels are within the range of terrestrial systems, as market available smartphones are used;
  - the received interference at the satellite will only be caused by their own smartphones and can be managed by the system internally under the supervision of the partner MNO;
- in the downlink:
  - the interference potential is caused by the PFD from the satellite needed for the D2D-IMT service provision, but affects the partner MNO phones only and can be managed by the system internally under the supervision of the partner MNO.

3.3.2 In-country MFCN protection

3.3.2.1 Intra-network TN protection (in-block, in-beam)

The protection of the intra-MNO TN network against the interference from the SN satellite stations is a subject of the partnership between the SNO and MNO, not a spectrum regulatory matter.

3.3.2.2 Inter-network TN protection (out-of-block / in-beam)

The coexistence between two different terrestrial MFCN networks is ensured by 3GPP technical specifications and the European Harmonised standard EN 301 908 [27]. But there are no European harmonised standards available for D2D-IMT space stations operating in MFCN frequency bands.

The terrestrial networks operating in adjacent blocks within the same frequency band are protected from each other by the adjacent channel leakage ratio (ACLR) and adjacent channel selectivity (ACS) of base stations and user equipment. In the case of coexistence between a TN and SN, the Harmonised standard EN 301 908 applies to the ground-based user equipment (UE), but there is no harmonised standard for D2D-IMT space stations. One way to protect the MFCN operating in adjacent frequency blocks in the same FDD frequency band is to apply an appropriate out-of-block downlink pfd limit for protecting UEs.

Inter-band protection between MFCN networks is ensured by the unwanted emissions limits, in addition of unwanted emissions general requirement (Spectrum Emission Mask and Cat-B spurious emissions), an additional requirement of unwanted emissions for the protection of its own receiver (uplink) or other base station (BS) receiver (uplink) in the same frequency band, as well as an additional requirement of unwanted emissions for the protection of BS receiver (uplink) operating in different frequency bands are defined in the 3GPP technical specification TS 38.104, sections 6.6.4.2 and section 6.6.4.3 [45]) and the related ETSI harmonised standard EN 301 908 [27]. There is no available European harmonised standard for satellite stations using MFCN frequency bands. Appropriate technical measures, such as suitable pfd limits on the ground, should be defined for protecting the downlink (UEs) and the uplink (base station receivers) of other MFCN networks in the same country.

3.3.3 Neighbouring country MFCN protection (out-of-beam)

Neighbouring country MFCN downlink can be in co-frequency or adjacent frequencies as listed in the lower part of Table 7.

Appropriate technical measures, such as suitable pfd limits, should be defined for protecting the downlink (UEs) and the uplink (base station receivers) of other MFCN in the frequency bands in section 3.2 in the neighbouring country.

The downlink protection towards the UE should take into account the quasi-omnidirectional antenna characteristics of the market available smartphones and the I/N requirement for the protection of terrestrial IMT service[3].

For the uplink protection, it should be taken into account that both active antenna systems (AAS) and non-AAS BS antenna are used for the IMT frequency bands between 698 MHz and 2690 MHz, AAS BS antenna is used for the IMT frequency band 3400-3800 MHz. Protection of both BS antenna types should be ensured.

For the cross-border coordination between terrestrial MFCN networks in neighbouring CEPT countries several ECC documents (see [16], [17], [18], [19]) already exist, defining trigger limits at the border / at 6 km distance from the border providing additional guidance (e.g. application of propagation model, modelling of the clutter losses and specific terrain information). Nevertheless, it has to be highlighted that cross-border coordination between MFCN networks is considered on the basis of equal access to spectrum to be able to extend their coverage at the border area with both terrestrial networks having similar network topologies and deployment characteristics. Those limits are not protection limits for terrestrial MFCN.

[3] The typical value is I/N = -6 dB

Also WRC-23 decided on pfd levels for the protection of IMT services from the use of high-altitude platform stations as International Mobile Telecommunications Base Stations (HIBS) (Resolutions 213 (WRC-23) [34], 218 (WRC-23) [36] and 221 (WRC-23) [37]), which means that the international community has already agreed that those limits protect UEs from harmful interference caused by HIBS. The suitability of levels from these Resolutions for the protection of terrestrial IMT service from harmful interference due to D2D-IMT needs to be studied.

Furthermore; different proposals for respective PFD limits for the protection of IMT, including aggregate effects caused by multiple satellites (of one or more D2D-IMT satellite systems) are being currently discussed in the context of the preparation for the WRC-27 AI 1.13.

One CEPT administration has published decisions on appropriate technical mitigations for protecting mobile systems where direct to device services in Mobile spectrum bands is facilitated [42]. The suitability of levels to the D2D-IMT networks from this CEPT administration still need to be studied.

Those ECC Recommendations, ITU Resolutions or related information are not directly applicable in the case of MFCN protection from D2D-IMT systems. The limits that they contain and their applicability for MFCN protection from D2D-IMT systems need to be studied and assessed in CEPT.

3.4 OTHER SERVICE PROTECTION

3.4.1 Protection of other incumbent services in adjacent bands

Protection of other adjacent-band incumbent services from D2D-IMT needs to be ensured. Technical studies need to be performed to identify which technical requirements are necessary to achieve protection.

Table 8 provides a list of examples of incumbent services in adjacent bands to MFCN bands. Those services need protection against interference from D2D-IMT satellite station unwanted emissions.

Table 8: Examples of adjacent bands services and applications needing protection

Adjacent band incumbent service and applications	Frequency range
Rooftop TV receiver	Below 694 MHz
Radio Astronomy (RAS)	1400-1427 MHz, 1660-1670 MHz, 2690-2700 MHz
Global System for Mobile Communications on Railways (GSM-R), Railway Mobile Radio (RMR)	919.4-925 MHz (Downlink) 874.4-880 MHz (Uplink) 1900-1910 MHz (TDD)
MSS	1518-1559 MHz (Downlink) 2483.5-2500 MHz (Downlink)
MetSat	1675-1710 MHz
MSS, including CGC	1980-2010 MHz (Uplink) 2170-2200 MHz (Downlink)
Distance Measuring Equipment (DME)	960-1215 MHz
Air Traffic Control (ATC) Radars, Radiolocation Radars	2700-3400 MHz
Governmental aerial UEs	1910-1920 MHz (TDD)
BSS	1452-1492 MHz

3.4.2 Protection of MSS use in the "MSS 2 GHz" bands and MSS 1.5 GHz band

The 1980-2010 MHz and 2170-2200 MHz MSS bands are used and licensed at the national basis in most CEPT countries and there is a harmonised EU regulatory framework. The 1518-1559 MHz MSS band is used for continued global safety-of-life communications and mission-critical voice and data services and use of these bands is intensifying. There is a need to establish appropriate regulatory limits for D2D-IMT satellite systems/networks, in order to protect the primary MSS systems / networks operations.

3.4.3 Radio Astronomy protection

Protection of RAS bands not only involves guarding against in-band emissions but also ensuring that out-of-band or spurious emissions from adjacent bands remain below specified limits. While selecting remote and geographically isolated areas is generally effective in protecting RAS systems from interference caused by Earth-bound active systems, interference from airborne and satellite-borne transmitters poses significant challenges to their successful operation. The RAS protection criteria are outlined in Recommendation ITU-R RA.769 [46] and Recommendation ITU-R RA.1513 [47] that recommends a data loss limit of 5% for the aggregate effect of all systems and 2% per system.

Given the sensitivity of RAS services and the target coverage area of D2D-IMT being remote regions, the impact of planned D2D systems on RAS needs to be considered and appropriate measures must be developed to adequately protect these systems.

The impacted RAS bands by D2D operations are listed in Table 9.

Table 9: Different scenarios for RAS affected by D2D-IMT

RAS frequency band	D2D-IMT downlink frequency band	Remarks
1400-1427 MHz	1427-1452 MHz	RR No. **5.340**, Primary band, RR No. **5.208B**
1610.6-1613.8 MHz	791-821 MHz (2nd harmonics)	Primary RR No. **5.208B**
1718.8-1722.2 MHz	1805-1880 MHz	RR No. **5.149**, RR No. **5.385**
2655-2690 MHz	2570-2620 MHz 2620-2690 MHz	RR No. **5.149**
2690-2700 MHz	2620-2690 MHz	RR No. **5.340**, Primary

4 REGULATORY CONSIDERATIONS FOR D2D

4.1 AUTHORISATION REGIME

4.1.1 Authorisation framework for D2D-MSS and D2D-IMT

4.1.1.1 D2D-MSS

For D2D-MSS, the regulatory and technical framework is already well established.

4.1.1.2 D2D-IMT

For most CEPT countries, it is not currently possible to authorise D2D-IMT without specific modifications in national regulatory framework or authorisations to mobile operators. The most common reasons mentioned by CEPT administrations are the limitation of current MNO licences that limit communication of cell phones to only terrestrial base stations in IMT bands and modifications potentially required to the Radio Frequency Allocation Table. Therefore, national authorisation regimes would need to be updated in order to authorise smartphones to communicate with satellites using IMT bands.

The relevant EC Decisions are targeting the harmonisation for terrestrial systems capable of providing electronic communications services on non-exclusive basis. An EC harmonised framework for D2D-IMT does not exist at the time this ECC Report was developed.

ECC Decisions on the harmonised utilisation of the MFCN bands, designate those bands for terrestrial use, while underlining the flexibility related to national needs and/or national licencing schemes. An ECC harmonised framework for D2D-IMT does not exist at the time when this Report was developed.

4.1.2 MNO-SNO agreement to access MNO spectrum

4.1.2.1 D2D-MSS

For the use of an authorisation of an MSS network under MSS allocation (D2D-MSS), no pre-requisite agreement with an MNO is considered as required.

4.1.2.2 D2D-IMT

For D2D-IMT, an MNO already holds the right of use for the band and a pre-requisite agreement is needed.

The regulatory problem concerns D2D-IMT where the satellite part can be considered as complementary to the national terrestrial network, and all conditions attached to the right of use still need to be fulfilled. The holder of the right of use (MNO) should demonstrate that conditions attached to right of use are still respected, plus any additional conditions related to coexistence with other services and systems following the introduction of D2D-IMT communications into the licence.

Also the notifying administration of the satellite system providing complementary coverage to the national terrestrial network may be located outside the country (even for national communications) and may not fall under the jurisdiction of that country, but under the notifying administration of the satellite system. The notifying administration and the satellite network/system that communicates with national smartphones shall be known by the administration of the MNO in advance to understand whose country is responsible to enforce any situation where the cooperation of the SNO is needed.

The complementary nature of D2D-IMT implies reliance on existing MNO spectrum holdings, and does not foresee independent authorisation to satellite operators.

4.1.3 Authorisations granted by auctions

4.1.3.1 D2D-MSS

For the use of an authorisation of a D2D-MSS network under MSS allocation, no auction process has been used in Europe.

4.1.3.2 D2D-IMT

The regulatory problem concerns D2D-IMT, where the needed modification of the authorisations may be complex due the original auctioning process for MFCN. In some CEPT countries, the MFCN frequency bands have been auctioned to MNOs and the conditions of the authorisations are based on those included in the auctions framework. Depending on the different national situations and current regulatory framework, authorisation conditions can either be adjusted during the lifetime of the authorisation upon request from an MNO after proper assessment by the administration, or when the current authorisation expires and the conditions for re-issuing the authorisations for new auctions are established. This assessment may include checking that the original framework for the provisions of authorisations in the frequency bands is not unduly impacted. Any modification may also require a consultation process when targeting services to the public. The timeframe to modify the licensing conditions could create obstacles or delays for enabling D2D-IMT services.

4.1.4 Visibility of Authorisations

According to the ECC Decision (01)03 (ECO Frequency Information System (EFIS)) [51] and the EC Decision 2007/344/EC [52] on the harmonised availability of information regarding spectrum use within CEPT / the European Community, providing information on the right of use is important for frequency bands of high economic interest where market mechanisms would apply, and where it is important to define a standard for the information required. This concept already applies in harmonised European IMT frequency bands and individual rights of use for D2D-IMT can be made visible.

The standard for right of use information in EFIS as follows:

- Lower frequency (numeric, EFIS format);
- Upper frequency (numeric, EFIS format);
- Simplex/duplex;
- License holder name and contact details;
- Technology in use;
- Start and expiry date / duration of the license;
- Information on location;
- National (tick box);
- Regional or local (free text field, link to national details);
- One transmitter (free text field, link to national details);
- Spectrum trading Yes/No (tick box);
- Relevance for ECO Report 03 (opt-out flag).

4.2 SPECTRUM ISSUES (TECHNICAL CONDITIONS, OTHERS)

4.2.1 Cross-border interference

4.2.1.1 D2D-MSS

For D2D-MSS services, the international coordination of MSS frequency assignments to satellites networks and systems is already mandatory under RR Nos. 9.7 and 9.11A, 9.12, 9.12A with satellite networks or systems and under RR No. 9.14 with terrestrial networks (including terrestrial services of country authorising or not authorising the D2D-IMT services). CEPT countries are already protected by the comments made according

to RR No. 9.52. Therefore the D2D-MSS system is already known and its notifying administration is obliged to protect the terrestrial networks of CEPT countries from downlink emissions by the ITU rules. The coordination of D2D-MSS terminals with terrestrial services of neighbour countries is also mandatory under RR No. 9.15 and No. 9.17.

4.2.1.2 D2D-IMT

The regulatory problem concerns D2D-IMT, where satellites use frequency assignments notified under RR No. **4.4**. RR No. **9.3** provides a process to resolve difficulties related to interference which may be unacceptable for existing or planned satellite networks or systems. The notifying administration of the D2D-IMT system endeavours to cooperate in joint efforts to resolve any difficulties. The concerned other administration can request additional relevant information that may be available, can request the assistance of the Radiocommunication Bureau and can also request progress reporting about the resolution of any difficulty. However, such process for resolving difficulties between D2D-IMT satellite downlinks and terrestrial services is not addressed and the RR do not specify pfd limits that would protect terrestrial networks (for countries authorising D2D-IMT or neighbouring country not authorising D2D-IMT).

The only regulatory protection of terrestrial services from D2D-IMT satellite downlink emissions is based on RR No. **4.4** that specify " *shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations*." But according to Rules of Procedure for RR No. **4.4**, the notifying administration of D2D-IMT satellites is not obliged to provide any prior demonstration that terrestrial networks of neighbouring country not authorising D2D-IMT will not be affected. The country authorising D2D-IMT on its territory has no RR obligation to carry out any coordination of the satellite downlink emissions with the neighbouring country as it is the responsibility of the notifying administration of the D2D-IMT satellites. It is also recognised that it is difficult to exactly know whose administration is the notifying administration of a D2D-IMT satellite system and the cooperation of the CEPT country authorising D2D-IMT is welcomed.

As seen in section 3.3.3, the CEPT neighbouring countries of an administration authorising D2D-IMT on its territory, will need a protection of their MFCN networks from D2D-IMT. Due to the lack of ITU rules, a new coordination requirement "Cross-border D2D interference" may be harmonised between CEPT countries by:

- informing CEPT of an authorised D2D-IMT systems and its notifying administration;
- developing ECC harmonised protection limits;
- developing ECC mechanism to ensure before the launch of the service that relevant limits protecting terrestrial networks in other countries will be respected. One potential way to achieve this would be to secure a commitment letter from the notifying administration (similar approach as for communications with satellite in SRD bands 862-870 MHz (see ECC Decision (25)02 [49]). Such an approach will ensure that the notifying administration of the D2D-IMT satellite system is identified.

4.3 ADMINISTRATIVE ISSUES

4.3.1 New national secondary allocation to the MSS in terrestrial bands

Apart from the international status of non-interference and non-protection under RR No. **4.4** some administration authorising D2D-IMT could decide to add a national secondary MSS allocation in MS bands for the specific purpose of operation.

Such a decision only concerns the territory of this administration and only give a national additional status to D2D-IMT terminals, by obtaining a dual status of terrestrial stations and Earth stations, so that at the national level they now need to comply with both terrestrial and earth stations provisions.

Such an issue may be reviewed after WRC-27.

4.3.2 Enforcement

Due to the current RR No. **4.4** nature of D2D-IMT, ITU information on satellites' filings of D2D-IMT systems is poor and in the absence of technical verification by the Radiocommunication Bureau, CEPT administrations are relying on their own monitoring system and analyses to cope with any difficulty involving such D2D-IMT satellite system. The identification (satellite operator/notifying administration) of existing D2D-IMT satellites can be a challenge.

For any technical difficulties mentioned in section 3.3.3 and section 3.4 about unauthorised connection or protection of MFCN networks and other services, the first regulatory requirement, before addressing any complaint, is to identify the concerned satellites and its notifying administration.

For any interference affecting terrestrial service in one CEPT country, the concerned administration shall react by sending interference complaint to the notifying administration of the D2D-IMT satellite system (RR Appendix **10**). Any CEPT country that has authorised D2D-IMT services in the interfered frequency bands will be implicated in the resolution of the interference by revealing the identity of the concerned satellites and associated ITU filing (e.g. identifying the notifying administration).

It is recognised that the use of RR No. **4.4** by D2D satellites networks only concerns derogation to the frequency allocation table of RR Article **5**. Other RR provisions are still mandatory (e.g. RR Articles **15.1**, **17** and **18.4**) that prevent the use of false and misleading D2D-IMT downlink signals and prohibit unauthorised interceptions of D2D-IMT uplinks from one country. A CEPT country discovering unauthorised D2D-IMT operations on its territory could claim for infringement to the Radio Regulation (RR Appendix **9**) based on RR No. **17.1** for unauthorised space-based interceptions of terrestrial IMT devices of another country and RR No. **15.1** for unauthorised misleading space-based downlinks that catch national IMT devices of another country.

It is of interest to CEPT to develop the knowledge of which D2D satellites are authorised to serve CEPT countries and their associated notifying administration to help on any enforcement issue. The cooperation of CEPT countries authorising D2D-IMT services is essential.

4.4 EQUIPMENT ISSUES

4.4.1 Standardisation

4.4.1.1 D2D-IMT

The problem concerns D2D-IMT because of the absence of standards that would ensure compliance with regulatory constraints:

- The D2D-IMT system is expected to communicate with standardised (3GPP compliant) terminals, hence there is no issue with standardisation;
- The satellite component of D2D-IMT systems that currently exist are based on proprietary solutions. Such systems do not follow international standards and specifications which are restricted in their scope and capabilities to the application for terrestrial networks. Such systems are operating under space assignments notified under RR No. **4.4** that have currently no existing international regulatory provisions or specifications, including harmonised methods for coordination and protection purposes. If a WRC concludes with international regulatory provisions for the coexistence between such satellites systems and also for the protection of terrestrial services from such satellite systems, there may be a need in ECC to review the necessity of standardisation;
- ECC currently does not need to explore standardisation of D2D-MSS and D2D-IMT.

The D2D-IMT network intends to communicate with current and future 3GPP-compliant handsets.

Some D2D-IMT systems intend to provide service to potential partner network operator's subscribers using standardised TN 3GPP roaming architecture and interfaces. These connections may utilize existing transport infrastructure, such as IP exchange (IPX), similar to that of terrestrial roaming connections in order to connect roaming interfaces, such as S6a and S8, to the operators existing core network.

Some other D2D-IMT systems intend to directly relay signals from the operator's own base station and core network directly to its subscribers leveraging transparent satellite payload.

4.4.1.2 D2D-MSS

For D2D-MSS, 3GPP TS 22.261 Rel.17 [53] describes the service requirements for next-generation services and markets that require the 5G system to be able to provide services using satellite access. It further specifies the configuration requirements and interactions between terrestrial 5G access and satellite-based access networks owned by the same operator or by an agreement between operators, providing examples of the use cases for the provision of services over 3GPP defined satellite-based access components.

While the 1610-1626.5 MHz / 1626.5-1660.5 MHz / 1525-1559 MHz and 1980-2010 MHz / 2170-2200 MHz / 2483.5-2500 MHz bands have long been allocated for MSS, there is a trend towards standardizing technology in these bands and share a harmonised design with TN. Draft new Recommendation ITU-R M.[IMT2020-SAT-SPECS] [48] contains the specifications for the radio interface of the satellite component of IMT-2020 as submitted by 3GPP for non-terrestrial networks (NTN).

Technical and operational parameters are in place via ETSI and 3GPP specifications such as in ETSI TS 138 101-5, 3GPP TS 38.101-5 [56] User Equipment (UE) radio transmission and reception; Part 5: Satellite access Radio Frequency (RF) and performance requirements with enhancements.

The 'Integration of satellite components in the 5G architecture' enhances features in the 5G Core architecture to support NTNs for several use cases, including coverage extension, IoT, disaster communication, global roaming, and broadcasting.

3GPP has identified two specific MSS frequency band ranges (S-band and L-band) recognised across all ITU Regions and compatible with the same duplex mode, FDD. These bands offer standardised solutions aimed at mitigating potential conflicts between MSS-based communication and existing cellular networks. Within these designated bands, 3GPP has specified bandwidth allocations of either 2x3 MHz, 2x5 MHz, 2x10 MHz, 2x15 MHz, or 2x20 MHz (for n255 and n256 only):

- 3GPP 5G bands n255: UL: 1626.5-1660.5 MHz and DL: 1525-1559 MHz;
- 3GPP 5G bands n256: UL: 1980-2010 MHz and DL: 2170-2200 MHz;
- 3GPP 5G bands n254: UL: 1610-1626.5MHz and DL: 2483.5-2500 MHz.

4.5 USE OF RR NO. 4.4.

4.5.1 Existing regulation measures

4.5.1.1 D2D-MSS

No issue for D2D-MSS (not operating under RR No. **4.4**).

4.5.1.2 D2D-IMT

The problem concerns D2D-IMT, because of the lack of procedure and coexistence limits/conditions and verified information by the Radiocommunications Bureau concerning the use of assignments notified under RR No. **4.4** by D2D-IMT satellites.

D2D-IMT operators have proposed to provide satellite-based service without an MSS allocation, meaning that their notifying administration must derogate from Article **5** of the Radio Regulations and let their operator provide service on a non-interference and non-protection basis according to frequency assignments notified under RR No. **4.4**.

According to the ITU Rules of Procedure, frequency assignments under RR No. **4.4**, which are brought into use, have to be notified to the Bureau. In the notification, the administration needs to include a confirmation that it has determined, prior to bring into use, any frequency assignments to a transmitting station operating

under RR No. **4.4** will not cause harmful interference into the stations of other administrations operating in conformity with RR and that it has determined the measures to avoid harmful interference and the measures to comply with the requirement and to immediately eliminate harmful interference pursuant to RR No. **8.5**.

ECC Report 305 [25] recommended that the operation of commercial and long term M2M IoT systems via satellite under RR No. **4.4** should be discouraged and avoided. But commercial IoT satellite systems have become available in the frequency band 862-870 MHz and the ECC revised this consideration for this specific band with the ECC Report 357 [50] and the ECC Decision (25)02 [49]. Some considerations for D2D-IMT networks are different from the specific situation in the band 862-870 MHz, but some considerations could potentially also be applied for the case of D2D-IMT.

It is noted that the WRC-27 has an agenda item (AI) 1.13 "to consider studies on possible new allocations to the mobile-satellite service for direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage, in accordance with Resolution 253 (WRC-23)" [40]. This Report deals only with the regulatory regime for national authorisation, which is not addressed by the WRC-27 AI 1.13. This Report proposes regulatory options that may need to be reviewed after the WRC-27.

Depending on the outcome of WRC-27 agenda item 1.13, CEPT countries may need to continue consideration of RR No. **4.4** for D2D operations. The European Commission has issued the Mandate to the CEPT on Complementary satellite Direct-to-Device (D2D-IMT) connectivity in terrestrial EU-harmonised frequency bands to CEPT.

When a CEPT administration is authorising D2D-IMT communications based on RR No. **4.4**, information exchange is important to address the concerns of other administrations and to avoid difficulties.

RR No. **4.4** states that:

"Administrations of the Member States shall not assign to a station any frequency in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations, except on the express condition that such a station, when using such a frequency assignment, shall not cause harmful interference to, and shall not claim protection from harmful interference caused by, a station operating in accordance with the provisions of the Constitution, the Convention and these Regulations".

The regulatory consequences according to the Rules of procedures on RR No. **4.4** are that derogations are limited to a limited set of provisions of the Radio Regulations:

- *1.2 The scope of the terms "in derogation of either the Table of Frequency Allocations in this Chapter or the other provisions of these Regulations" is specified in No.8.4 by the indication that the "other provisions" shall be identified and included in a Rule of Procedure. The Rules of Procedure on No. 11.31 provide a complete list of these "other provisions".*
- *1.3 The scope of No. 4.4 is therefore limited to derogations to the Table of Frequency Allocations and to the provisions listed in the Rules of Procedure on No. 11.31 with regard to the "other provisions". In particular, administrations intending to authorize the use of spectrum under No. 4.4 still have the obligation, under Sections I and II of Article 9, Nos. 11.2 and 11.3, to notify to the Bureau "any frequency assignment if its use is capable of causing harmful interference to any service of another administration".*

According to the Rules of Procedure on No. **11.31**, the "other provisions" are limited to the following:

- *"conformity with the Table of Frequency Allocations, including its footnotes and any Resolution or Recommendation which is referred to in such a footnote;*
- *the successful application of No. 9.21, when mention is made of that provision in a footnote (see also Rules of Procedure relating to Nos. 9.21 and 11.37);*
- *all "other" mandatory provisions that are contained in Articles 21 to 57, in Appendices to the Radio Regulations and/or in Resolutions that are relevant to the service in the frequency band in which a station of that service operates."*

Therefore, derogating to Article **5** of the Radio Regulations, D2D-IMT satellite systems still need to be compliant will all other requirements from the Radio Regulations.

In order to increase the transparency, WRC-23 instructed the Radiocommunication Bureau (BR) to insert the indication of the frequency assignment submission under RR No. **4.4** at the Summary Table of the Special Section or Part. In addition, to facilitate information sharing, WRC-23 instructs the BR to make any information it may have regarding notification and bringing into use of frequency assignments under RR No. **4.4** available in an easily accessible format, such as publishing it in the BR's website and implementing a new filter option in the ITU Space Explorer Data Analytics tool. The shared information could include a list of filings that are using RR No. **4.4** as well as historical data, including the date of receipt of these assignments. In addition, the BR is also instructed to periodically inform administrations on the updated information regarding notification and bringing into use of frequency assignments under RR No. **4.4** made available by the BR in its website and to invite the notifying administrations to take steps to cancel the RR No. **4.4** assignments if no longer in use. WRC-23 urges administrations when using frequency assignments under RR No. **4.4** to fully comply with the objectives and purpose of this provision, including the RoP related to RR No. **4.4**.

CEPT currently does not have a harmonised authorisation framework for D2D-IMT under RR No. **4.4**. At the time of development of this ECC Report the following options are available for CEPT administration.

The CEPT administration that authorises D2D-IMT services in a certain frequency band:

- can restrict authorised D2D-IMT communications to and from satellites that are capable of being identified (identification signal) and have known ITU filing and notifying administration;
- can restrict authorised D2D-IMT communications to and from satellites that are able to justify that they operate under a licence from a notifying administration that commit to respect any defined limits by that CEPT administration to protect other services;
- can restrict authorised D2D-IMT communications to and from satellites that are able to justify that they operate under a licence from a notifying administration that includes explicit reference to prohibition in RR No. **15.1** (misleading signals), Article **17** and No. **18.4** (interceptions);
- can inform other CEPT administration of their intention to issue a D2D-IMT authorisation;
- can restrict authorised D2D-IMT communications to and from satellites operating under assignments that have been previously notified according to RR No. **11.2** and noting No. **11.3** (D2D-IMT system is capable of causing harmful interference) and No. **11.8** (non-conforming assignments are recorded for information only);
- can restrict authorised D2D-IMT communications to and from satellites that operate in compliance with the Radio Regulations.

The CEPT administration that requires protection from D2D-IMT services in a certain frequency band:

- can identify the protection requirements (services and protection levels);
- can inform CEPT administrations of the protection requirements;
- can monitor publications which include frequency assignments under RR No. **4.4** and communicate the protection requirements to the concerned notifying administration. It should be noted that if no comments are received from an administration under RR No. **9.3** within the commenting period, it may be assumed that the concerned administration has no objection. It is recognised RR No. **9.3** is normally limited to comment addressing satellites networks/systems, but the ITU tool for those comments extend to terrestrial networks.

The CEPT administration that is the notifying administration of a D2D-IMT system in a certain frequency band is required to:

- conduct analyses to not cause harmful interference to other services;
- identify measures in order to eliminate harmful interference to other services.

4.5.2 Possible concept for the protection of terrestrial services (D2D-IMT case)

A CEPT administration wishing to implement D2D-IMT service operated under RR No **4.4** needs to consider the protection of existing services and spectrum use in other CEPT countries. Protection limits are needed to ensure the protection of terrestrial services and spectrum use from D2D satellite downlink emissions. The following outlines a possible approach which administration may use for the protection of terrestrial services noting that the actual future limits are still under study at the time of writing this Report.

This concept is not an ITU coordination but follows similar steps as the current framework of threshold levels set out in RR Appendix **5** for frequency bands with MSS allocation and terrestrial services. CEPT administrations could use these steps:

- define a baseline threshold level (share the agreed level with the notifying administration of the satellite system). For example, if the illumination from a D2D satellite downlink is below the threshold level, terrestrial networks can be considered as protected;
- in presence of several D2D networks in close geographic proximity, some aggregation could be considered and all concerned notifying administrations of D2D systems should collectively manage the aggregate effects;
- based on bilateral agreement which may include consideration of any applicable aspect that provides some mitigation, there may be the possibility to exceed from threshold level discussed above. In general, the Radio Regulations allow deviation from limits in the territory of any country whose administration has so agreed.

The above is only to be understood as a concept which could be considered between administrations (concerned CEPT administrations and the notifying administration of the satellite system) in the context of implementing D2D-IMT under RR No **4.4** in absence of an MSS allocation and international regulatory framework.

4.6 OTHER ISSUES

The following issues are of interest for regulators and administrations, but not strictly in the scope of this Report.

4.6.1 Mobility management and roaming

Seamless service continuity between D2D and terrestrial cellular networks is expected by users, depending on the availability of respective coverage.

Mobility management is a feature of the 3GPP 5GNR standard which applies seamlessly to TN and non-terrestrial networks (NTN). Roaming and/or handover procedures can be supported by NTN-capable smartphones from TN (4G or 5G) to NTN and vice-versa.

Some satellite network architectures used for providing D2D-IMT supplementary coverage to an existing MFCN network may not rely on roaming.

4.6.2 Network identity and registration handling

Some D2D services will need to obtain public land mobile network (PLMNs) either from their partner MNO or from the regulatory body of each country where service is being provided. The intent is for MNOs to configure their SIMs to select the D2D network as a last resort if no other coverage is available. Some other direct to device services simply complement the coverage of an existing MFCN, hence not requiring a separate PLMN.

For example, since the SpaceX D2D network acts as an LTE serving carrier, no subscriber SIM credentials are stored within the network itself. Instead, as with all roaming networks, authentication of customer devices is with their home (MNO) network, using the serving (SNO) network as a transit mechanism. Customer devices will register with their home network and all traffic to and from the device will be traverse a tunnel between the serving and home network.

The 3GPP 5GNR standard at network level has mechanisms for network identification and terminal entry into the network. When used for NTN, these mechanisms equally apply and have been optimised to enable a quick terminal entry on the NTN network so that transitioning to/from TN can happen with minimal impact (e.g. avoid communication drop).

4.6.3 Interoperability/flexible, hybrid radio access networks

The 3GPP 5GNR standard covers the Radio access involving the user equipment and the network, as well as the Service aspects, so that it applies independently whichever smartphone or network provider is involved. The protocol being inclusive of TN and NTN from its Release 17, it allows by construct interoperability among networks.

4.6.4 Integration of the satellite component into the global mobile networks

The 5GNR standard with NTN features defines the end-to-end service level interfaces that allow to integrate the satellite connectivity transparently for the overall network.

In particular, as per Release 17 requirements (see 3GPP TS 22.261 [53]), for a 5G system with satellite access: the 5G system shall support service continuity between 5G terrestrial access network and 5G satellite access networks owned by the same operator or owned by different operators having an agreement. As regards roaming, a 5G system with satellite access shall enable roaming of UE supporting both satellite access and terrestrial access between 5G satellite networks and 5G terrestrial networks. UEs supporting satellite access shall support optimised network selection and reselection to PLMNs with satellite access, based on home operator policy.

4.6.5 Emergency services

Emergency services encompass emergency communications and emergency messaging. Both are regulated services subject to specific requirements from national administrations.

In line with the above requirements, a 5G system with satellite access is able to determine a UE's location in order to provide service (e.g. route traffic, support emergency calls) in accordance with the governing national or regional regulatory requirements applicable to that UE. In effect, network verified UE location is introduced in Release 18 to comply with the administrations' requirements.

Given the obvious interest of consumers in being able to be located by emergency services organisations in emergency situations, MNOs, SNOs and emergency organisations all have a clear incentive to cooperate with each other to facilitate this capability.

The type of support that providers are capable of contributing to emergency service organisations depends on the technical capabilities of the relevant telecommunications network.

Obligations within EU countries (European Electronic Communications Code) exist regarding the Emergency services: ability for users to call the number 112 free of charge, ensure rapid response and handling of such calls and for operators to provide caller location information with certain accuracy. ECC Report 324 [57] provides further information in this respect. While not applicable to all CEPT members, the European Electronic Communications Code (EECC) serves as a base framework to address the handling of emergency communications. Article 109 of the EECC notes that Member States must ensure that users can access emergency services free of charge through emergency communications and by using the single European emergency number 112.

Routing emergency communications to the most appropriate Public Safety Answering Point (PSAP) is a challenging task and should be ensured in D2D connectivity as well. Presently, network architecture implemented by SNOs to facilitate such routing, is not mandated to be reported to the regulators. However, failure to adequately address the need to provide emergency services and fulfil user expectations regarding their availability could result in consequences for the user.

In order to ensure the efficacy of emergency services, location information must be shared with the PSAP to ensure that emergency services are not delayed in responding to a request for help. Article 109(6) of the EECC notes that it must be ensured that the caller's location is made available to the most appropriate PSAP without delay. This requirement applies solely to fixed and mobile service providers and aligns with terrestrial network architectures equipped with base stations, nevertheless, a common standard regarding timeliness and accuracy of D2D location information would assist in allowing emergency service providers to respond adequately to emergency calls.

Conversely, as per the new delegated regulation supplementing the EECC, the implementation of caller location criteria (although not specifically Advanced Mobile Location (AML)) is a priority for EU member states. Therefore, D2D providers should be encouraged to take appropriate measures to align with the practice of providing location information as precisely as possible. Further initiatives could include amending European standards concerning AML, or the adoption of tailored software requirements for PSAPs.

Most of European PSAPs feature next-generation 112 capabilities and are equipped to engage with IP-based communications that would include satellite communications directly. However, there are still systems in CEPT countries where PSAPs can only receive voice calls. In situations where PSAPs lack the ability to receive text-based communications, alternative solutions are imperative to ensure that emergency communications via satellite reach the appropriate PSAP. In practice, some D2D providers establish relay centres to bridge this gap and ensure that emergency calls are not compromised as a result.

Expansion of infrastructure should continue to ensure that all PSAPs have the capabilities of receiving and actioning D2D emergency communications.

Furthermore, the EECC requires Members States to ensure that users with disabilities have substantially similar access to emergency services as non-disabled persons. This is especially applicable to users with disabilities traveling between Member States. This requirement is currently set upon terrestrial network but D2D system should ensure that it meets the standard of accessibility imposed on other emergency communication services. This includes accessibility for visually and hearing-impaired persons such as implementing speech-to-text services.

Ultimately, user experience with the D2D system, particularly concerning emergency communications, necessitates a transparent procedure. This procedure should inform users of any transition between cellular and satellite connectivity, enabling them to adjust their expectations in terms of quality of service and expedition regarding the respective service provided.

In addition to usage of emergency communications during normal times, during natural disasters, terrestrial communication infrastructure is vulnerable to damage or destruction. Communication during these periods of disaster is particularly important and directly related to saving lives. Ensuring that the above pre-requisites are met, would allow D2D functionality to provide connectivity where terrestrial infrastructure is not available, acting as an additional means of communication for emergency response teams and affected individuals, helping to coordinate rescue efforts and facilitate recovery.

4.6.6 Lawful interception

RR Articles **17** and **18.4** will be addressed through the use of encryption, ensuring that secrecy of communications. Terrestrial operators are already well-versed in implementing appropriate policies and protocols to protect the privacy of its users and the secrecy of their communications, while complying with all applicable local laws governing lawful intercept and legal demands by relevant authorities for stored customer information. In the direct-to-device model, the SNO would, in partnership with its MNO, support law enforcement requests if required.

Adding the use of a satellite for D2D service, the ability to perform interception is still in the core network that could be managed by the MNO or the SNO. When interception may occur within the satellite payload, there could be additional requirements to comply with local national interception legislations.

Lawful interception is widely considered a matter of national security; thus its implementation typically falls within the discretion of governments. However, among CEPT countries, there is a certain level of common practice. The Budapest Convention on Cybercrime which nearly all CEPT Member States are a party of enforces interception of content and communications data to all operators. In addition, the European Telecommunications Standards Institute (ETSI) plays an active role in establishing lawful interception standards. Its specifications are not only widely accepted throughout Europe but also by numerous countries outside the continent. However, it should be noted that the enforcement of the regulatory rules and ETSI standards are left to discretionary powers of law enforcement authorities and regulators. In EU, European Electronic Communications Code creates a broad obligation and leave discretionary powers to member states, creating a fragmented framework [54].

In the case of regenerative satellite payload, cooperation between SNOs and MNOs involves multiple network nodes where communications may be intercepted. For the network architecture comprising of a Gateway operated by the SNO and a core network operated by the MNO which has already implemented a core network compliant with local regulations governing lawful interception, and thus assumes responsibility for addressing lawful interception queries.

Hence, the existing regulatory framework encompasses lawful interception requirements, regardless of the adopted D2D system approach. Moreover, the selection of the location for the interception holds significant importance in both cases; opting to place the equipment outside Europe or in a challenging country could elevate security risks. In Europe, there is no clear practice regarding location of the ground infrastructure. Some Member States set this as a requirement. Therefore, each D2D connectivity model must be assessed based on the network architecture and specific requirements of the Member State.

In the 5GNR standard, the following service level requirement applies: A 5G satellite access network connected to 5G core networks in multiple countries shall be able to meet the corresponding regulatory requirements from these countries (e.g. Lawful Interception).

4.6.7 Role of the EU Union Secure Connectivity program in this context, a program established under Regulation (EU) 2023/588/EU

Note: the current Regulation (EU) 2023/588 of the European Parliament and of the Council of 15 March 2023 [55] only covers the period 2023-2027 but not beyond.

In February 2024 the European Commission released a White Paper "How to master Europe's digital infrastructure needs?", discussing - inter alia - the future radio spectrum provisioning for developing satellite communications like direct -to-device.

Und the topic "Mastering the transition to the digital networks of the future - policy issues and possible solutions" the ECC considers, that for the completion of 5G roll-out and timely 6G deployment, a more cooperative approach between the national and European level is of vital importance for EU competitiveness. In this context, areas that deserve to be considered and possibly lead to relevant actions include:

i) EU level planning of sufficient spectrum for future use cases;
ii) strengthening EU level coordination of auction timing;
iii) considering more uniform spectrum authorisation landscape.

No wireless service can be deployed without the availability of sufficient spectrum resources. This would include evolving and new areas such as vertical use cases, 6G, IoT applications, Wi-Fi, local spectrum use. Also, this includes rapidly developing satellite communications, ensuring secure government and commercial applications, including direct-to-device satellite connectivity, using spectrum allocated for mobile satellite and, if appropriate, terrestrial services. In this context it should be considered whether, to ensure that new technology advancements are rolled out across the EU at the same time, an EU spectrum roadmap towards 6G should be enshrined in the law and enforced in a coordinated way by all Member States.

4.6.8 Competition

Possible competition issues may need to be addressed taking into account competition/equity between MNOs, between SNOs or competition SNOs / MNOs.

5 NECESSARY TECHNICAL STUDIES

The European Commission has issued the Mandate to the CEPT on Complementary satellite Direct-to-Device (D2D-IMT) connectivity in terrestrial EU-harmonised frequency bands to CEPT.

This Mandate addresses feasibility, coexistence and compatibility studies for the use of relevant EU-harmonised bands, originally designed for terrestrial wireless systems providing ECS, by satellite systems providing complementary D2D-IMT connectivity. It aims to ensure the protection of existing uses, including their evolution and development, within these bands and adjacent ones, both across Member States' borders and at the EU's external border. It further addresses the development of EU-harmonised technical conditions.

In preparation for WRC-27 CEPT is developing its position for agenda item 1.13.

6 CONCLUSIONS

This Report has explored the regulatory and technical elements related to the national authorisation of satellite-based D2D communications using existing smartphones. Two distinct approaches have been identified:

- D2D-MSS, making use of established MSS allocations and frameworks;
- D2D-IMT, leveraging terrestrial MFCN spectrum for which cooperation between MNOs and SNOs is necessary.

For D2D-MSS, the regulatory and technical framework is already well established. MSS bands in the L-band and S-band are internationally harmonised, supported by ITU Radio Regulations, and underpinned by CEPT/EU decisions. As such, D2D-MSS deployments can be implemented today under existing licensing regimes without the need for new regulations.

For D2D-IMT, an agreement is needed between the SNO and MNO that holds the rights of use of the MFCN bands.

For D2D-IMT, however, regulatory challenges remain. These include:

- the lack of harmonised procedures and conditions at both CEPT and ITU level, since D2D-IMT operations rely on RR No. **4.4**;
- the absence of harmonised limits to protect MFCN networks and other services in band and adjacent bands, both nationally and across borders, from D2D-IMT operations;
- the need to adapt or amend existing national authorisations frameworks to allow communications of already available standardised handsets with a satellite within harmonised MFCN bands;
- difficulties in enforcement and identification of D2D-IMT satellite systems and their notifying administrations.

While D2D-IMT services have been made available for some frequency bands, further studies are required to define regulatory limits and conditions to protect MFCN networks and other services, particularly in cross-border contexts and adjacent bands. Further CEPT work in the framework of the Mandate from the European Commission and ongoing preparations for WRC-27 (agenda item 1.13) are crucial.

In conclusion, D2D-MSS can be authorised within the current framework, whereas D2D-IMT requires additional regulatory development and harmonisation. The rapid evolution of D2D technologies highlights the importance of CEPT administrations exchanging information, developing common approaches, and ensuring that new authorisation frameworks both enable innovation and safeguard existing services.

When a CEPT administration is authorising D2D-IMT communications based on RR No. **4.4**, information exchange is important to address the concerns of other administrations and to avoid difficulties.

Future work should focus on:

- developing harmonised technical conditions and limits to protect MFCN and other services from D2D-IMT;
- enhancing information sharing and transparency on D2D-IMT systems when operating under RR No. **4.4**;
- develop or revise ECC regulatory provisions to enable D2D-IMT operations;
- take into account WRC-27 results.

ANNEX 1: BACKGROUND ON SATELLITE BASED DIRECT-TO-DEVICE (D2D) COMMUNICATION DEVELOPMENTS FOR IMT USER EQUIPMENT

A1.1 RELEVANT EC AND CEPT DOCUMENTS AND EUROPEAN TERMINAL LICENSING FRAMEWORK

RSPG established in November 2012 a working group to develop a response to the European Commission's Request for an Opinion on spectrum issues concerning Licensed Shared Access. The RSPG Opinion on LSA approved in November 2013 provides the following definition:

- "A regulatory approach aiming to facilitate the introduction of radiocommunication systems operated by a limited number of licensees under an individual licensing regime in a frequency band already assigned or expected to be assigned to one or more incumbent users. Under the Licensed Shared Access (LSA) approach, the additional users are authorised to use the spectrum (or part of the spectrum) in accordance with sharing rules included in their rights of use of spectrum, thereby allowing all the authorised users, including incumbents, to provide a certain Quality of Service (QoS)".

Whereas the complete list of reference documents is contained in Annex 3 the following ECC Decisions and Reports are of special relevance for the satellite based D2D service provision and system implementation in CEPT countries. Due to the specific geographical situation in Europe (large number of small countries) managing the interference situation (cross border coordination) and harmonizing the use of the spectrum are the most important aspects to be considered on the RF side:

- Licensed frequencies for MS in CEPT countries as the first decision step for selecting frequencies to provide D2D services in a particular country (see ECO Report 03 [21]);
- Introduction of a parallel operation of MSS and MS (e. g. by means of Complementary Ground Component) (see ECC Decision (06)09 [4] and ECC Decision (06)10 [5]);
- Cross border coordination for MFCN in various frequency bands (see ECC Recommendation (15)01 [19], ECC Recommendation (14)04 [18], ECC Recommendation (11)05 [17], and ECC Recommendation (01)01 [15]).

It is noted that the European regulation should maintain the principles of technical sovereignty, security and reliability for the benefit of a harmonised market. There could be analogies of this MNO/SNO concept with the LSA concept developed in RSPG in the past.

A1.1.1 Potential future MSS allocations

Alongside the frequency ranges outlined in the above table, the recent World Radiocommunications Conference (WRC-23) has agreed to conduct studies to potentially allocate additional MSS spectrum.

Regarding MSS, there are 3 different agenda items that focus on MSS allocations with overlapping bands. AI 1.13 specifically focuses on bands already allocated to mobile which can be used for D2D connectivity while 2 other agenda items deal with generic MSS services which could include D2D and low data rate MSS services.

Agenda Item 1.12 considers, based on the results of studies, possible allocations to the mobile-satellite service and possible regulatory actions in the frequency bands 1427-1432 MHz (space-to-Earth), 1645.5-1646.5 MHz (space-to-Earth) (Earth-to-space), 1880-1920 MHz (space-to-Earth) (Earth-to-space) and 2010-2025 MHz (space-to-Earth) (Earth-to-space) required for the future development of low-data rate non-geostationary mobile-satellite systems, in accordance with Resolution 252 (WRC-23).

Agenda Item 1.13 considers studies on possible new allocations to the mobile-satellite service for direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage, in accordance with Resolution 253 (WRC-23). The frequency range is defined as between 694/698 MHz and 2.7 GHz taking into account the IMT frequency arrangements addressed in the most recent version of Recommendation ITU-R M.1036.

Finally, Agenda Item 1.14 considers possible additional allocations to the mobile-satellite service, in the frequency bands 2010-2025 MHz (Earth-to-space) and 2160-2170 MHz (space-to-Earth) in Regions 1 and 3 and 2120-2160 MHz (space-to-Earth) in all Regions.

A1.1.2 Terrestrial-satellite partnerships

A number of D2D announcements have recently been made public.

A1.1.2.1 Lynk Global

Similarly, Lynk plans to install so-called cell towers in space providing D2D service to standard 3GPP mobile phones and 3GPP cellular IoT devices, based on partnership agreements with terrestrial MNOs. Meanwhile 3 "satellite-cell-towers" are launched, carrying a 5G payload. So far two-way commercial and emergency messaging services has been verified.

Lynk's initial service has been operational in Palau in partnership with Palau National Communications Corporation (PNCC) and provide coverage to all of Palau's 300+ islands and surrounding waters.[4] Lynk is also active in Solomon Islands where it is partnered with local MNO bmobile[5], and in Papua New Guinea, in partnership with local MNO Telikom[6].

A1.1.2.2 AST Space Mobile

AST SpaceMobile aim is to bring space-based mobile broadband services directly to unmodified smartphones. Following launch of its BlueWalker test satellites in April 2019 and September 2022, AST SpaceMobile successfully demonstrated the technical feasibility of delivering 5G broadband satellite connectivity to standard, unmodified terrestrial mobile devices. In September 2024, AST SpaceMobile launched five first-generation BlueBird Block 1 (BB1) satellites, offering 10 times higher throughput than the BlueWalker test satellites. In early 2025, AST SpaceMobile successfully completed the first video calls with its mobile network operator partners, Vodafone, AT&T, and Verizon, using standard, unmodified smartphones[7].

AST SpaceMobile's next-generation BlueBird Block 2 (BB2) satellites, will feature the largest communications array ever to be deployed in low Earth orbit for commercial service, delivering up to 10 times the bandwidth capacity of the first-generation BB1 satellites in bands <1GHz. AST Space Mobile has begun deployment of its low band BB2 satellites in 2025. AST Space Mobile is also planning for its mid-band (>1GHz) space-based cellular broadband network which will include the MSS 2 GHz band and will begin deployment in 2026.

Vodafone and AST SpaceMobile established a joint venture company (SatCo) to drive European-wide space-based mobile broadband coverage. Mobile operators covering 21 EU member states and other European countries have already expressed an interest in using the service with commercial launch expected in 2026.

A1.1.2.3 SpaceX

In 2024, SpaceX introduced its Direct-to-Device enabled Starlink payloads carrying an advanced LTE eNodeB modem and a large phased array antenna for connecting LTE cell phones from space.

The intended partnership model with a terrestrial Mobile Network Operator (MNO) maintains the end-to-end responsibility at the respective MNO holding the radio frequency license(s) and operating the terrestrial networks. The satellites work as additional base stations complementing the service area of the terrestrial MNO under its existing authorisations and supervision.

SpaceX D2D-IMT provides service to mobile subscribers on partner networks with SMS messaging since 2024. These offerings will be enlarged by voice and low data throughput applications. SpaceX has publicly announced partnerships with seven MNOs across four continents. In addition to Salt in Switzerland, this includes T-Mobile in the United States, Optus in Australia, One NZ in New Zealand, KDDI in Japan, Rogers

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[4] Lynk, Lynk and Palau National Communications Corporation (PNCC) Begin Initial Sat2Phone Service to PNCC Mobile Subscribers

[5] Lynk, Lynk and bmobile Solomon Islands Limited Begin Sat2Phone Service for bmobile Subscribers

[6] Via Satellite, Lynk Launches Initial Satellite to Cell Service in Papua New Guinea With Telikom Limited

[7] Vodafone and AST SpaceMobile complete world's first space-based 5G call using a conventional smartphone, https://www.vodafone.com/news/technology/vodafone-ast-spacemobile-world-first-space-based-5g-call-conventional-smartphone

Wireless in Canada, and Entel in Chile and Peru. SpaceX is working collaboratively with MNOs to augment existing terrestrial networks and to extend connectivity to previously unreachable areas.

In addition to partnerships from operators, In February 2024, Global Satellite Operators Association (GSOA) and Global System for Mobile communications Association (GSMA) (the global organization representing mobile operators and organizations across the mobile ecosystem and adjacent industries) announced a cooperation agreement involving D2D. Collaborative efforts are expected to focus on innovative technologies and applications that harness the combined capabilities of satellite and mobile networks. These include integrating 5G, facilitating IoT connectivity, utilizing remote sensing, and providing global coverage solutions[8].

A1.1.3 D2D-MSS systems

Some notable market developments have taken place between SNOs and device or chipset manufacturers. These partnerships include:

A1.1.3.1 Skylo and Bullitt

Skylo[9], a non-terrestrial network (NTN) operator with a focus on facilitating connectivity between disparate locations, has entered into a partnership with Bullitt Group, a British smartphone manufacturer, as Bullitt's satellite connectivity partner for its two-way satellite messaging smartphone. The Bullitt messaging service will connect via satellite through Skylo's network of partner geostationary satellite constellations in the event that there is no mobile or Wi-Fi coverage[10].

In collaboration with Skylo and MediaTek, a leading global semiconductor company, Bullitt has developed the world's first standards-based 3GPP approach to satellite or 'direct-to-device' non-terrestrial network (NTN) connectivity.[11].

A1.1.3.2 Globalstar - Apple

Globalstar's constellation of satellites and ground stations on six continents currently provide affordable, high-quality MSS to more than 781000 end user customers in more than 120 countries worldwide. Globalstar's service links are in the bands 1610-1618.725 MHz/2483.5-2500 MHz and its feeder and TT&C links are in the bands 5091-5250 MHz/6875-7055 MHz. Significantly to this Report, pursuant to Globalstar's agreements with Apple, users of the iPhone 14 and above will have Globalstar MSS connectivity at their fingertips when no terrestrial network is available, including during emergency situations where communications are critical and often lifesaving.

Apple was the first phone manufacturer to integrate satellite connectivity into standard phones with the release of the iPhone 14 in 2022[12]. This service operates within Globalstar's existing MSS satellites and is available in 16 jurisdictions, including CEPT member states, for the purpose of providing an emergency satellite service[13].

Apple has expanded the capabilities of its satellite messaging system on the iPhone. The latest iOS updates have extended the availability of satellite messaging beyond that of emergency messaging, with the option of using satellite connectivity for location and general messaging when cellular and Wi-Fi connections are unavailable. The Messages app will automatically prompt users to connect to the nearest satellite when they

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[8] Global Satellite Operators Association, GSOA and GSMA Join Forces to Boost Innovation in Satellite & Mobile Convergence

[9] ECC Project Team FM44 input contribution FM44(26)002, PC results of the draft ECC Report 373, Annex 11

[10] Skylo, Bullitt Selects Skylo's Direct-to-Device Satellite Service for Its Newly Announced Smartphones and Two-Way Messaging Service

[11] Skylo, MediaTek and Skylo Collaborate on Next-Gen 3GPP NTN Satellite Solutions on Smartphones and Wearables

[12] Apple, Emergency SOS via satellite available today on the iPhone 14 lineup in the US and Canada

[13] Apple, Emergency SOS via satellite on iPhone 14 and iPhone 14 Pro lineups made possible by $450 million Apple investment in US infrastructure

are outside the range of cellular service. This will permit iPhone users to send and receive text messages, emojis and tapbacks via iMessage and SMS[14].

It should be noted that this satellite connectivity feature uses a propriety MSS technology in the iPhone, providing D2D capability. This feature is currently not based on the 3GPP NTN standard.

A1.1.3.3 Huawei - China Telecom

The Huawei Mate 50 smartphone series is equipped with the capability to transmit emergency service text messages via China's BeiDou satellite navigation system. The latest model, the Mate 60 Pro, features enhanced satellite calling and messaging capabilities utilising China's three Tiantong-1 satellites in geostationary orbit. The service is currently available only in China. China is planning to launch one or more low Earth orbit (LEO) satellite broadband constellations in the coming years with the objective of expanding direct-to-device (D2D) services[15].

A1.1.3.4 MSS Association

The Mobile Satellite Services Association (MSSA) is a non-profit association formed to support the efforts of advanced NTN solutions providers, including terrestrial mobile and satellite operators, original equipment manufacturers, infrastructure providers, chip vendors, to provide enhanced mobile connectivity globally and seamlessly. Specifically, the MSSA seeks to promote and advance the emerging ecosystem for advanced NTN services, including direct-to-device. The MSSA is focused on facilitating a global ecosystem utilizing spectrum already allocated and licensed for MSS and well-suited for integration into a broad range of mobile devices through open, standards-based solutions. Among other things, the MSSA, advocates for policies and standards that would facilitate widespread adoption of satellite-based mobile services, enabling seamless roaming across networks[16]. The MSSA has established working groups on various NTN topics and its membership includes to technology developers and service providers across the value chain[17].

A1.1.4 Global market trends

With an addressable market of 400 million subscribers by 2035, the mass consumer market for D2D services is significant[18]. However, it is still unclear how much consumers are willing to pay for D2D messaging, voice, and data services beyond emergency situations, which tend to be free.

For commercial offerings, D2D providers may charge a monthly fee for users to send and receive messages outside of their cellular operator's terrestrial coverage area or recoup such service expenses by increasing handset prices. As a potential data point, analysts at Raymond James[19] estimated that roughly 200000 Android phone users will spend around US dollars (USD) 3 per month for satellite messaging by the end of 2023, growing to 4.5 million by 2026. GSMA projects that the market will be valued at over USD 30 billion by 2035, with the consumer market accounting for USD 19.9 billion itself. The other market segments are enterprise B2B and government accounting for USD 10.39 billion and USD 2.45 billion respectively[20].

From the MNO perspective, one potentially popular model could be bundling D2D services into premium price plans. A different model is a pay-as-you-use structure under which MNOs sell D2D connectivity packages, where customers would sign up for satellite services only during periods when they might be traveling outside terrestrial cellular coverage areas, as suggested by AST SpaceMobile's early IPO filings in 2020.

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A1.1.5 Customer demands

Mobile customers expect reliability and resilience, affordability, accessibility, inclusivity and relevance. Consumers are likely to be sensitive to initial pricing and operators might expend more effort in encouraging and educating consumers to increase uptake. While messaging is not expected to constitute a major piece of the eventual D2D revenue opportunity, initial operator strategies may provide a first look into future business models and their eventual impact on consumer choices and prices. D2D providers can expect two main types of users: Firstly, the specialised user, who already owns a satellite phone or satellite-powered gadget and is likely to pay a premium for complementary D2D satellite connectivity on their handset for incremental convenience. For example, satellite smartphone maker Bullitt is charging around USD 4.99 per month for two-way satellite-based messaging on its new phones[21]. The other user type is a non-specialised smartphone user, who is likely to be more reluctant to pay additional fees for complementary D2D satellite connectivity.

In areas where deploying terrestrial networks is challenging due to technical or cost constraints, such as in remote or underserved regions, the satellite component plays a crucial role in ensuring reliable connectivity. This integration not only addresses the limitations of terrestrial infrastructure but also guarantees that connectivity needs are met, regardless of geographical barriers.

It should be noted that the demand for D2D services would significantly increase in times of disasters or network outages. Terrestrial networks may be disrupted during disasters, posing significant challenges in managing emergency situations and potentially resulting in substantial human and economic consequences. During such crises, D2D technology may assist in providing a reliable communication lifeline, ensuring the resilience of connectivity and bolstering emergency response efforts.

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ANNEX 2: LIST OF REFERENCES

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