ATU-R INFORMATION PAPER

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OUTLOOK AND REGULATORY, TECHNICAL AND OPERATIONAL IMPLICATIONS OF DIRECT-TO-DEVICE SATELLITE TECHNOLOGY

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Executive Summary

This paper discusses the regulatory, operational, and technical aspects of satellite Direct-to-Device (D2D) communications between satellites and end-user devices. Several factors have led to the growing demand for D2D applications. Portions of the world rely on satellite connectivity as they have little ground-based infrastructure providing coverage. In Africa, 41% of the population resides beyond the reach of terrestrial infrastructure. Advances in satellite technology and satellite service standardization, such as the 3GPP Non-Terrestrial Networks (NTN) standards, have driven momentum for D2D, which can help provide critical connectivity for underserved populations, delivering significant social and economic development gains, as well as expand connectivity across multiple large and diverse segments, including industrial, government, agriculture, automotive, and others. D2D applications provide a quick solution to complement terrestrial network coverage, addressing gaps in connectivity where traditional networks fall short.

Two approaches to D2D are being contemplated, which differ depending on whether they use spectrum allocated to the *mobile-satellite service* (MSS) for service links (referred to as “D2D-MSS” in this Paper), or spectrum currently allocated only to the *mobile service* (MS) and identified for the terrestrial International Mobile telecommunications (IMT) systems for service links (referred to as “DC-MSS-IMT” in this Paper). While spectrum allocation is one of the key factors determining the D2D satellite communication implementation, it is also driven by different aspects and advanced technologies including the advanced modulation and error correction techniques to facilitate efficient data transmission, multibeam antennas, advanced transceivers and inter-satellite links (ISL) to support simultaneous communications with thousands of devices and between different satellites.

The first approach termed MSS D2D utilizes spectrum already allocated to the mobile satellite service (MSS) and in some cases leverages 3GPP NTN standard specifications enabling features to be implemented in both the Radio Access Network (RAN) and User Equipment (UE), ensuring compatibility and multi-vendor interoperability, and eventually integration across terrestrial and non-terrestrial radio interface. This approach falls within the existing International Telecommunication Union (ITU) MSS allocations and national licensing frameworks, where they exist, that enable today’s MSS services – particularly for the L-band and S-band MSS allocations. It is important to note that national licensing is required to authorise companies operating under a D2D-MSS approach. This approach takes advantage of the work of 3GPP to bring satellite capability to mass-market mobile devices through the introduction of non-terrestrial networks into industry-developed specifications. This will simplify and harmonize the implementation of satellite connectivity in the global 5G ecosystem.

For the MSS D2D solution, terrestrial and satellite networks typically operate on different frequency bands, allowing them to coexist in the same geographic area without causing any harmful interference to each other. As a result, D2D-MSS can fill the terrestrial coverage gaps

today with overlapping coverage without the need for physical separation distances. D2D-MSS therefore enables coverage extension without affecting the capacity of terrestrial networks or hindering the Mobile Network Operators (MNO) ability to utilize IMT frequency bands when using nation-wide spectrum, similar to DC-MSS-IMT as discussed below. However, D2D-MSS has two variants, one which utilizes a proprietary interface and which communicates with modified smartphones, and on which necessitates collaboration with mobile chipset vendors to support relevant MSS frequencies and NTN functionalities in their user equipment to enable D2D services.

The second approach, referred to as DC-MSS-IMT, aims to address already commercialised off the shelf mobile handsets (i.e., user equipment pre 3GPP Release–17 specifications) by utilizing spectrum already allocated to the Mobile Service (MS) and licensed to an MNO with which the Satellite Network Operator (SNO) establishes a partnership to use part of the MNO spectrum subject to national regulatory framework for satellite direct-to-device. This approach ensures that D2D application is compatible with the terrestrial mobile service and the D2D service complies with existing obligations of the terrestrial license holder to co-exist with terrestrial networks without causing harmful interference. This delivery model relies on satellite operators entering in commercial agreement with MNO in order to enable transmitting and receiving in spectrum allocated and licensed to the terrestrial mobile service to bring satellite capability to mass-market mobile devices.

For D2D applications, a number of technical and regulatory issues can benefit from clarification to ensure they can enable coverage extension using satellite technology without affecting the capacity of terrestrial networks and causing harmful interference to incumbent services. For example, some countries have reviewed national regulations, with some even adopting new rules to enable new D2D services, while global discussions at the ITU look towards developing internationally-harmonized regulatory framework. National and international regulations for DC-MSS-IMT will need to be developed before systems can safely co-exist for DC-MSS-IMT models,

Collaboration between Satellite Network Operators (SNO), Mobile Network Operators (MNO), and regulatory bodies is crucial for unlocking the full potential of satellite D2D connectivity and usher in a new era of ubiquitous and seamless communications for Africans.

It is an important time for ATU administrations to be studying the impact of D2D technologies in the region. With the correct and balanced regulation, D2D applications promise to be a useful solution in helping narrow the coverage gap and provide new safety-of-life capabilities.

Abbreviations and acronyms

2G	Second generation
3G	Third generation
3GPP	3rd Generation Partnership Project
4G	Fourth generation
5G	Fifth generation
ATU	African Telecommunications Union
BEREC	Body of European Regulators for Electronic Communications
CEPT	European Conference of Postal and Telecommunications Administrations
D2D	Direct-to-Device
D2D-MSS	Direct-to-Device in mobile-satellite service
DC-MSS-IMT	Direct Connectivity between Mobile-Satellite Service space station and IMT user equipment
eMBB-s	enhanced mobile broadband via satellite
EU	European Union
FCC	Federal Communications Commission
GIA	Geographically independent area
HRC-s	high reliability communications via satellite
IMT	International Mobile Telecommunications
IoT	Internet of Objects
ITU	International Telecommunication Union
LEO	Low Earth Orbit
MENA	Middle East and North Africa
mMTC-s	Massive machine type communication via satellite
MNO	Mobile Network Operators
MS	Mobile Service
MSS	Mobile satellite service
NGSO	Non-geostationary orbit
NR	New Radio
NTN	Non-Terrestrial Networks
RAN	Radio Access Network
RIT	Radio interface technologies
RSPG	Radio Spectrum Policy Group
SCS	Supplemental Coverage from Space
SMS	Short message service
SNO	Satellite Network Operators
SRIT	sets of radio interface technologies
SSA	Sub-Saharan Africa
UE	User Equipment
URLLC	Ultra-reliable low latency communications
WRC-27	World radiocommunication conference - 2027

1. Introduction

Innovation in mobile device and satellite technologies, globally harmonized standards, and technology convergence are enabling Direct-to-Device (D2D) communications between satellites and conventional terrestrial mobile handsets and other end-user devices, such as IoT sensors. D2D technologies present exciting new opportunities to complement services currently provided by mobile network operators, to close the digital divide and improve network coverage in Africa. D2D technology will likely fulfil the following use cases: (i) complement existing terrestrial mobile networks to expand network operator coverage to connect underserved or unserved areas, and (ii) facilitate short-term, and urgent requirements when other network infrastructures are compromised or not available such as during natural disasters. These use cases are expected to be particularly valuable to Africa.

Two approaches to D2D are being contemplated, which differ depending on whether they use spectrum allocated to the *mobile-satellite service* for service links (referred to as “D2D-MSS” in this Paper), or spectrum allocated to the *mobile service* and identified for terrestrial International Mobile Telecommunications (IMT) systems for service links (referred to as Direct Connectivity between Mobile-Satellite Service space station and IMT user equipment “DC-MSS-IMT” in this Paper).

Direct connectivity from a satellite to mobile handset currently available in the market is a useful tool for expanding coverage and may offer new business opportunities for mobile network operators. However, DC-MSS-IMT is a nascent promising emerging technology and no harmonized international regulatory provisions exist. Some MSS operators are providing D2D-MSS services in bands already allocated to MSS in the Radio Regulations on a primary basis under MSS filings with global coverage. Some licensed DC-MSS-IMT operators are currently providing these services in some national jurisdictions.

As at February 2025, 27% of sub-Saharan Africa (SSA) and 49% of Middle East and North Africa (MENA), were connected to the mobile internet by the end of 2023[1] while 60% (SSA) and 47% (MENA) lived within the footprint of a mobile broadband network but were not connected, a figure known as the usage gap. The usage gap exists because of affordability, digital literacy and other factors. D2D may not support connecting the segment of the unconnected population that fall within the usage gap. The coverage gap, the percentage of the population living outside a mobile broadband connection, may get some support from D2D and in 2023 stood at 13% in SSA and 4% in MENA. Using satellites to provide Direct to Device (D2D) services to areas of the globe that currently have no mobile coverage has the potential to grow into a significant market opportunity for the telecommunications industry, as well as Governments who are looking at how best to address the digital divide and establish future intervention programmes.

[1] https://www.gsma.com/r/wp-content/uploads/2024/10/The-State-of-Mobile-Internet-Connectivity-Report-2024.pdf

Given the link budget and spacecraft constraints experienced in satellite network components compared to terrestrial one, the satellite component cannot support the same level of technical performance as the terrestrial component. D2D's current service offering uses low-bandwidth – SMS, and SOS only. Future plans aim to use more bandwidth and power to improve capacity and capability to potentially provide voice and enhanced mobile broadband via satellite (eMBB-s), massive machine type communication via satellite (mMTC-s) and high reliability communications via satellite (HRC-s), or just broadband from space.

This paper explores key issues concerning regulatory, operational, and technical aspects of satellite Direct-to-Device (D2D) communications between satellites and end-user devices.

2. Technical, Operational and Regulatory Considerations

2.1. Direct-to-device approaches

Implementation of D2D can be grouped based on radio frequency spectrum allocation. Two different approaches for the provision of Direct-to-Device communications have formed in the industry, namely:

- DC-MSS-IMT: Services which use spectrum allocated to the Mobile Service (MS) and to IMT and which is assigned to Mobile Network Operators (MNO).
- D2D-MSS: Services which use spectrum allocated to the Mobile Satellite Service (MSS) and which is assigned to Satellite Network Operators (SNO).

To understand the two D2D approaches, we first need to define Non-Terrestrial Networks (NTN). NTN encompasses various satellite services and their applications, as well as technology defined by 3rd Generation Partnership Project (3GPP). The 3GPP standardization effort aims to achieve economies of scale across sectors. D2D is a sub-category of NTN services related to the direct connection to mass market user equipment.

2.1.1. D2D-MSS

Within D2D-MSS there are two distinct variants currently present in the market, namely:

1) Systems which use the 3GPP NTN standards to provide direct to device services in the MSS frequency bands: enhancements to the 5G NR standard have been introduced from Release 17 onwards which enable the integration of Non-Terrestrial Network (NTN) capabilities by smartphones using MSS spectrum. Such NTN capabilities are not specific nor to a particular SNO nor to a particular phone manufacturer, allowing for interoperability between networks. Such services rely on the adoption of the 3GPP standards by the chipset manufacturers.

2) Services which use a proprietary system and handsets: these systems integrate proprietary MSS technology directly into the smartphone to enable D2D capability, but are not based on the 3GPP NTN standards. These solutions are specific to a particular SNO and a phone manufacturer, and do not require any changes to the satellite system operating within the existing MSS spectrum allocation.

Satellite Network Operators licensed to provide mobile satellite services can provide direct to device services in globally allocated MSS bands. The L-band (1-2 GHz) and S-band (2-4 GHz) have been widely allocated and licensed for MSS by regulators and a stable international regulatory and technical framework exists. There are direct-to-device applications available today that operate according to this framework. That regulatory environment is already in place to allow for the provision of new D2D-MSS applications subject to national regulatory framework.

2.1.2. DC-MSS-IMT

Some Satellite Network Operators (SNO) have fitted their spacecraft with payloads capable of communicating with commercialised mobile handset on existing IMT and MS spectrum bands. These systems aim to augment network coverage for mobile networks using the same frequency bands as MNO. This approach is new and novel. Currently, there is no internationally harmonised framework agreed at ITU level. This presents technical and regulatory challenges that require consideration in order to ensure that the DC-MSS-IMT application is compatible with terrestrial systems in the mobile service operating in the same bands, as well as with incumbent services operating in adjacent bands. However, this model has allowed nation-wide services in some countries around the world including the Unites States of America, United Kingdom, Japan, New Zealand, Australia and others.

DC-MSS-IMT applications and systems are at their inception, and present several technical and regulatory issues that require study and clarification to ensure that they can coexist with incumbent services operating both in band and in adjacent bands. With that being said, given the availability of existing solutions ready to deliver the service today, some countries around the world adopted national frameworks to allow this service in their country, including defining rules to ensure protection of incumbent services and applicable cross-border limits to protect services in neighbouring countries.

2.2. Capabilities of D2D solutions

i. D2D-MSS

Report ITU-R M.2514-0[2], adopted in 2022 describes the vision, requirements and evaluation guidelines for IMT-2020 satellite radio interfaces. Adding a satellite component to IMT-2020

[2] Report ITU-R M.2514-0: Vision, requirements and evaluation guidelines for satellite radio interface(s) of IMT-2020 - https://www.itu.int/dms_pub/itu-r/opb/rep/R-REP-M.2514-2022-PDF-E.pdf

could extend the coverage of the IMT-2020 service in underserved and unserved areas where complementing the terrestrial component is most relevant.

The satellite component of IMT-2020 covers three usage scenarios of which the enhanced mobile broadband satellite (eMBB-s) usage scenario and the massive machine type communications satellite (mMTC-s) usage scenario are satellite variants of eMBB and mMTC defined in Recommendation ITU-R M.2083-0[3]. The satellite component does not address the ultra-reliable low latency communications (URLLC) scenario, but covers a satellite specific high reliability communications usage scenario (HRC-s). The satellite IMT-2020 usage scenarios with associated use cases are illustrated in Figure 1.

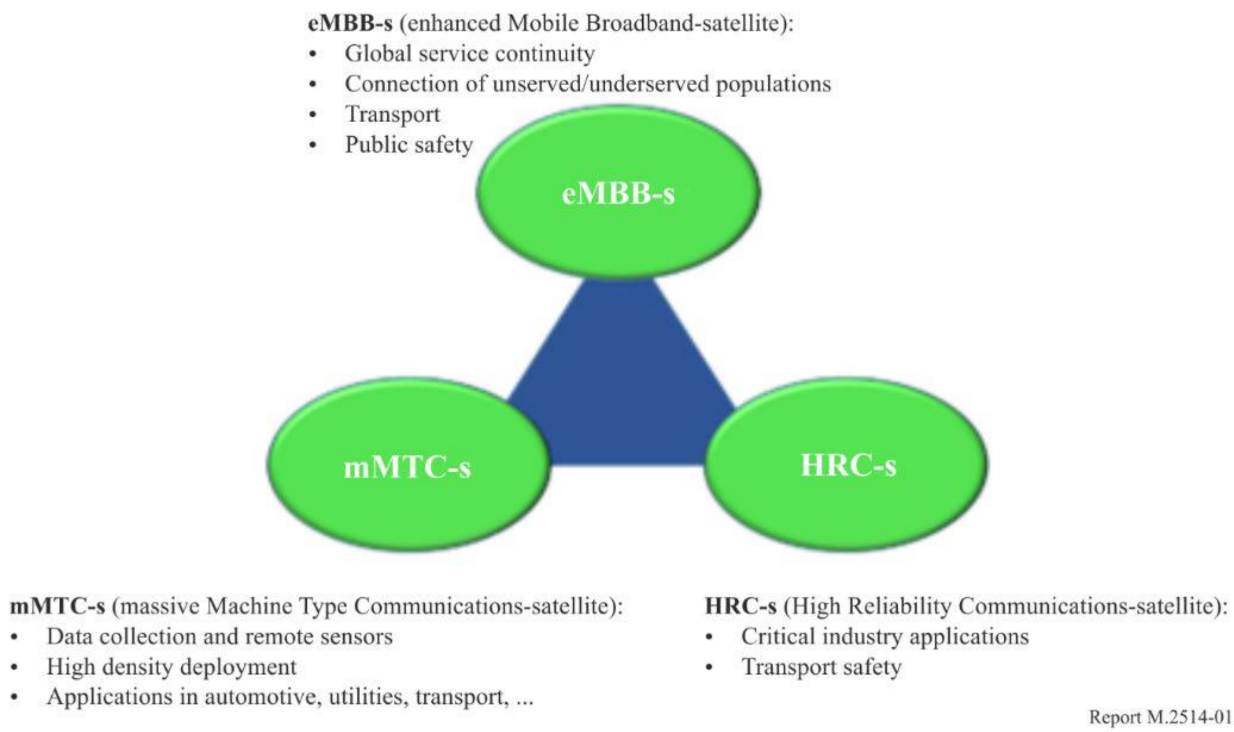

Figure 1: Satellite IMT-2020 usage scenarios with associated use cases

2.3. Potential use cases and benefits

In Africa, over 57% of the population lives in rural areas and 43% in urban and suburban areas[4]. Indeed, in some countries, the rural population can be as high as almost 80%, such as Niger, Malawi, Rwanda, Burundi, etc. These large rural populations are not nearly as connected as urban and suburban populations. Indeed, while 50% of urban dwellers are connected, this figure drops to 15% in rural areas. This is the lowest percentage of connected users of any region in the world.

[3] Recommendation ITU-R M.2083-0, IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond: https://www.itu.int/dms_pubrec/itu-r/rec/m/R-REC-M.2083-0-201509-I!!PDF-E.pdf
[4] https://data.worldbank.org/indicator/SP.RUR.TOTL.ZS?locations=ZG.

Moreover, only 59% of the population resides within reach of terrestrial backbone infrastructure in Africa; however, this varies sharply by country. For example, in Democratic Republic of Congo, only 27% of the population lives within a 25 km range of an operational fibre node; in South Sudan, only 4% live within fibre reach. In March 2021 most mobile connectivity is 2G or 3G, i.e., low bandwidth; 4G represents only 15% of mobile connections throughout the continent[5]. Hence, one of the remaining challenges in Africa is therefore to provide connectivity outside the terrestrial network coverage areas and in marginal coverage areas.

D2D-MSS uses spectrum already allocated to the mobile satellite service (MSS), where MSS operators can provide services directly into any form of MSS-enabled mobile device. This integration enables a seamless transition on continuation of services between terrestrial and satellite networks. As D2D technology develops, it is expected to become more capable of encompassing use-cases supporting not only low data rates, but also broadband data. In the case of D2D-MSS operating on 3GPP NTN standards, integrating the capability to operate in the MSS bands requires adoption by the chipset manufacturer. This case can support various applications from narrowband to IoT, and can support high-quality voice, rich messaging, and video services, and can connect to a range of supported devices, including smartphones, wearables, IoT devices, and more.

A number of mobile operators are considering DC-MSS-IMT systems as a cost-effective mechanism for expanding network coverage, especially where terrestrial base station deployment is not feasible.

The specific benefits of D2D applications may include:

1) Connect users outside areas of terrestrial mobile coverage;
2) Backup basic connectivity option in instance of terrestrial network outage (e.g., natural disaster, power interruption);
3) Emergency response in areas without terrestrial coverage;
4) Enterprise IoT;
5) Automotive connectivity outside of terrestrial coverage;
6) Reduced latency for real-time applications;
7) Seamless offloading of network traffic for terrestrial networks.

2.4. Development of D2D devices

There are two types of D2D-MSS currently in the market: those that use the 3GPP Release 17 NTN standards to deliver MSS to standard mobile phones, and those that deliver MSS to modified smartphones with integrated proprietary MSS transceivers. The following steps describe the evolutionary path for the development and availability of D2D devices and their standardization.

[5] https://www.ses.com/blog/africa-connectivity-outlook-2022-and-beyond.

Step 1: Satellite to specialized handset (Satellite Phones)

Traditional satellite-capable handsets (or commonly known as satellite phones) have been in operation since the late 1990s and are still used today, particularly in government, military and rural cases. These devices were used to communicate with satellites in the low-Earth-orbit and geostationary-orbit satellites to provide voice, messaging and limited data services. These devices were proprietary i.e., manufactured to work with specific satellite network only. The specific hardware and subscription services are expensive to attain, constricting these devices to niche applications.

Step 2: Satellite to modified smartphones

Modified smartphone means smart phone manufactured with some additional features to meet technical specifications of the satellite space segment. Device-to-Device Modified Smartphones refer to smartphones enhanced with features that allow direct communication between devices without the need for a central network. This approach can improve connectivity, reduce latency, and enable new applications. Direct-to-smartphone satellite communication was introduced to the mass market in late 2022 with an Emergency SOS functionality serviced by an MSS system. More manufacturers have followed, working with other satellite providers around enhancing Device-to-Device communication capabilities using satellite technology. This collaboration aims to integrate satellite connectivity into mobile devices, enabling them to communicate directly with satellites for improved coverage and functionality, particularly in remote areas. Key aspects of the agreement include:

1) Satellite Connectivity: The partnership allows smartphones and IoT devices to use satellite network for direct communication, expanding the reach beyond traditional cellular networks.
2) Device-to-Device Communication: This integration enables devices to communicate directly with each other via satellite, facilitating services such as messaging, location sharing, and emergency communications, even when terrestrial networks are unavailable.
3) Technology Integration: Vendors are collaborating on chipsets that support these features, ensuring that a broader range of devices can access satellite services seamlessly.
4) User Experience: The aim is to provide a user-friendly experience where D2D communications can be initiated without requiring additional hardware or complicated setups.
5) Market Expansion: This agreement is significant for addressing the needs of users in remote regions, enhancing the functionality of smartphones and IoT devices in various sectors, including emergency response, maritime, and outdoor activities.

Modifications must be made to the device to communicate with existing satellite systems, without sacrificing the expected form of the phone. Therefore, direct-to-smartphone connectivity is primarily driven by phone-makers with intimate knowledge of device design to enhance offerings relative to their competition. Bearing in mind the limitations of the devices and existing satellite constellations, these features will only provide SOS and two-way messaging, rather than voice or data.

Step 3: Satellite to unmodified devices

Satellite to unmodified devices typically refers to systems or services designed to work seamlessly with existing hardware without requiring any modifications. This concept is common in areas like satellite internet, cloud gaming, or data backup solutions.

This means a normal mobile handset (2G, 3G, etc.) communicate with satellite system within any modification, that is the term “unmodified devices”. Over the past few years, a new group of satellite companies have entered the mobile phone connectivity market. They intend to launch a new breed of satellites to communicate with unmodified phones through spectrum assigned to mobile network operators. These satellite companies work directly with mobile network operators to offer coverage using existing cellular phones and spectrum assigned to MNO.

Step 4 :3GPP Standards

There is also an overarching industry effort to pursue a standards-based approach to satellite networks. The governing body of cellular standards, 3GPP, has outlined several specifications for NTN in Release 17 and 18 namely specifications such as narrowband IoT in the ratified Release 17 standard and 5G New Radio, which is an existing Release 18 study item. From Release 18, new 5G and upward devices and chipsets may have 5G NTN compatibility, but there are still questions about which constellations and spectrum assets will be used. The Release 17 is looking to add satellite spectrum bands in the Mobile Satellite Services (MSS) in the future smart phone.

The emergence of satellite integration in the 3GPP ecosystem is the result of a joint effort between mobile and satellite industry stakeholders, along with strong support from verticals, such as automotive, transport, public safety, media/entertainment, agriculture, and others. The 3GPP defined NTN standard supports seamless interoperability across terrestrial and NTN components. This standard creates the opportunity for the addition of the satellite network component in the 5G New Radio (NR) systems, delivering the promise of a ubiquitous mobile system that can support the “Anywhere, Anytime, Any Device” Objectives.

The frequency bands n256 (MSS allocated S-band) and n255 (MSS allocated L-band) have been defined as part of the 3GPP Release 17, while some other bands are being defined as part of Release 18. Some of these MSS allocated frequency bands are not incorporated in today’s smartphones, thereby an increased collaboration is occurring with mobile chipset vendors to support relevant MSS frequencies in smartphones. The definition of current and additional frequency bands in the 3GPP standards allows for the creation of a global market for satellite enabled user equipment with an economy of scale.

Regarding equipment standards for D2D-MSS, 3GPP Release 17 enhances features in the 5G Core Architecture to support NTN for several use cases, including coverage extension, IoT, disaster communication, global roaming, and broadcasting.

2.5. Spectrum aspects of D2D applications

2.5.1. D2D-MSS

D2D-MSS services are provided by conventional MSS systems. These systems operate in bands already allocated globally to the MSS by the International Telecommunication Union (ITU) on a primary basis, providing service to a variety of specialised terminal types. The following L-band and S-band allocations are designated for the mobile satellite services in ATU countries:

1) 1518 - 1525 MHz (space-to-Earth) paired with 1668 - 1675 MHz (Earth-to-space)[6]
2) 1525 - 1559 MHz (space-to-Earth) paired with 1626.5 - 1660.5 MHz (Earth-to-space)
3) 1610 - 1626.5 MHz (Earth-to-space and space-to-Earth)
4) 2483.5 - 2500 MHz (space-to-Earth)
5) 1980 - 2010 MHz (Earth-to-space) paired with 2170 - 2200 MHz (space-to-Earth).

D2D-MSS enables satellites to connect to mobile handsets enabled with the necessary antenna and chipset configuration (e.g. using 3GPP n255/6) and making use of mobile satellite service spectrum, including in L-band and S-band. 3GPP has identified for NTN[7],[8] two specific MSS frequency band ranges recognized across all ITU Regions, following the duplex mode defined by the ITU table of frequency allocations:

1) 3GPP 4G/5G bands n°255 dealing with MSS L-Band frequencies: Tx: 1626.5 - 1660.5 MHz and Rx: 1525 - 1559 MHz,
2) 3GPP 4G/5G bands n°256 dealing with MSS S-Band frequencies: Tx: 1980 - 2010 MHz and Rx: 2170 - 2200 MHz.

Measures for co-existence between MSS and other services are laid out by the Radio Regulations. Within these MSS frequency bands, 3GPP recommends bandwidth allocations of either 2x5 MHz, 2x10 MHz, 2x15 MHz, or 2x20 MHz; more capacity and bandwidth can be provided in larger blocks of spectrum. Further improvements and additions to the 3GPP standards are currently under study. This includes adding the “extended L-band” MSS frequency bands 1518 - 1525 MHz and 1668 - 1675 MHz. ITU-R Working Party 4B has initiated a procedure to evaluate the candidate radio interface technologies (RIT) and sets of radio interface technologies (SRIT). At the October 2024 meeting of WP4B, 3GPP Release 17 was evaluated and approved as RIT/SRIT for the satellite

[6] Currently not included as 3GPP-NTN band but included in a 3GPP WI with expected completion in March 2025

[7] Non-terrestrial network (NTN) refers to a Radio Access Network (RAN), which provides non-terrestrial access with 5G New Radio (NR), 4G NB-IoT or 4G eMTC radio interfaces to user equipment by means of an NTN payload embarked on an airborne or space-borne NTN vehicle and an NTN gateway (see 3GPP TS 38.300). The underlying technology, maturity, deployment model, and commercial timelines of a given NTN will vary.

[8] See 3GPP 38.101-5, NR; User Equipment (UE) radio transmission and reception; Part 5: Satellite access Radio Frequency (RF) and performance requirements, https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3982

component of IMT-2020. The ITU-R is expected to complete the development of the Satellite component of IMT-2020 interface specification Recommendations by May 2025.

2.5.2. DC-MSS-IMT

DC-MSS-IMT enables satellites to connect directly to existing off the shelf mobile handsets using terrestrial mobile spectrum, which serves as a complementary solution to terrestrial mobile coverage, especially in areas where such coverage is unavailable or lacking. This variant allows satellite networks/systems to utilize frequency bands allocated to the mobile service and identified for IMT, frequency bands that MNO use to transmit signals between existing mobile handsets and base stations. Using the mobile service frequency bands would leverage existing terrestrial mobile handsets and their associated chipsets.

On an international level, World radiocommunication conference-2027 (WRC-27) has been tasked with studying the technical, operational, and regulatory elements of D2D in terrestrial bands between 698 MHz and 2.7 GHz under agenda item 1.13. WP 5D and WP 4C are conducting studies pursuant to WRC-27 agenda item 1.13. The following list of frequencies is currently under study for possible implementation of DC-MSS-IMT.

Table 1: List of the possible candidate IMT frequency arrangements for satellite direct communication with IMT user equipment

Directionality	
Uplink (MHz)	**Downlink (MHz)**
807-849	852-894
880-915	925-960
832-862	791-821
698-716 776-798	716-746 746-768
698-748	753-803
1 427-1 470	1 475-1 518
1 920-1 980	2 110-2 170
1 710-1 785	1 805-1 880
1 850-1 920	1 930-2 000
1 710-1 780	2 110-2 180
2 000-2 020	2 180-2 200
2 010-2 025	1 880-1 920
2 305-2 320[1]	2 345-2 360[1]
2 500-2 570	2 620-2 690

Note 1: Working Party 5D noted that member states have also deployed in parts of the 2 300 - 2 400 MHz band using a FDD arrangement, however it is not reflected in the latest version of Recommendation [ITU-R M.1036](ITU-R M.1036).

However, it should be noted that the list of frequency bands to be studied is not final yet and Member States are free to provide further proposals to WP 4C regarding the frequency bands to be studied. These and the adjacent frequency bands are allocated to a range of services and used by various systems and technologies. The use of these frequency bands for new DC-MSS-IMT satellite systems introduces new potential interference issues that are expected to be addressed in the ITU-R studies.

2.6. Regulatory aspects

2.6.1. D2D-MSS

The D2D-MSS approach offers the ability to provide comprehensive coverage using globally harmonized MSS spectrum allocations. It minimises interference risk by utilizing existing MSS-allocated spectrum in both L and S bands, which have long-standing regulations defined in the ITU Radio Regulations and Recommendations to manage potential interference issues. D2D-MSS does not require any spectrum used currently by mobile network operators (MNO).

D2D-MSS operating on a proprietary system and which use modified smartphones with integrated MSS transceivers do not require any additional changes from the chipset manufacturer. Such services are able to operate within the established rules and globally harmonized MSS spectrum, and generally do not require any additional regulatory rules.

When deploying D2D-MSS, devices incorporating the 3GPP Release 17 NTN frequencies gain terrestrial and satellite connectivity access with interference and/or compatibility issues already being studied and addressed. This is because the spectrum utilized by both the terrestrial service and the satellite component already have their separate allocations, thus mitigating the need for additional interference analysis or operational limitations.

MSS already authorized in various countries would not require additional regulatory frameworks to protect other services when deploying D2D-MSS using the same MSS bands already in use. Co-existence and interference management between competing D2D-MSS systems in the same bands is addressed during the ITU satellite coordination and notification process. Some studies have shown that this approach of D2D-MSS applications using the 3GPP Release 17 bands could be challenging in terms of interference with incumbent MSS users in L-band and S-band[9]. For example, D2D-MSS smartphones could cause in the uplink direction interference to satellite receivers of existing systems. Further studies on intra service coexistence are therefore required to assess these coordination challenges with existing MSS users.

D2D-MSS is already possible in some jurisdictions without the need for administrations to adopt new regulations. Some ATU administrations have existing national regulations to enable the use of MSS terminals throughout their territory.

[9] https://www.mdpi.com/2227-7080/11/4/110

Regulatory bodies play a critical role in expanding access to the MSS spectrum for the future development of direct satellite connectivity to end-user devices to complement the terrestrial network coverage. To meet the growing demand for this service, regulators must preserve existing MSS spectrum. Two agenda items (A.I.), 1.12 and 1.14, will consider additional MSS spectrum at the next World Radiocommunication Conference in 2027 (WRC-27).

2.6.2. DC-MSS-IMT

DC-MSS-IMT applications should comply with national regulations and will need to ensure coexistence and protection of incumbent services operating in-band and in adjacent bands, including the systems operating under the mobile service.

D2D-IMT requires changes to the existing regulatory framework to allow satellite operators to use part of the spectrum assigned to mobile network operators. This includes allowing satellite use in the frequency bands allocated to the mobile service and ensuring that coexistence with the terrestrial mobile service is possible. Indeed, this approach could raise new issues of interference and coexistence with existing spectrum users, which require careful study and implementation of appropriate rules. Before national authorizations are granted to facilitate D2D operations in the spectrum allocated and licensed to the terrestrial mobile service, technical studies need to address unresolved issues, including out-of-band emissions, cross-border interference, and satellite-to-satellite interference, amongst others.

In the absence of an ITU regulatory framework, some countries have authorized operators to deliver services based on ITU RR Article No. 4.4, which states:

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.

Irrespective of the existence of a regulatory framework, this DC-MSS-IMT approach requires satellite operators and MNO to establish partnerships or enter into an agreement to access IMT spectrum licensed to MNO. DC-MSS-IMT is a developing radio application and a number of regulatory issues still need to be addressed. These may include:

1) Definition of roles of satellite network operators and mobile network operators;
2) Addressing interference management, potentially requiring exclusion zones and/or interference management techniques on operations to mitigate interference;
3) Determining measures to resolve potential interference to the IMT terrestrial networks and incumbent services in-band and adjacent bands;
4) Bilateral/multilateral cross-border agreements;

5) Satellite-to-satellite co-existence in the same and adjacent frequency bands;
6) How to ensure protection of IMT terrestrial networks and existing services and how the intended DC-MSS-IMT systems can meet those limits;
7) Development of inclusive frameworks that promote competition and do not prevent new entrants to the market.

Some large-landmass countries around the world countries, such as USA[10], Australia[11], have developed national regulatory frameworks for DC-MSS-IMT. It is noted that these countries have fewer concerns about cross-border interference due to their large size.

3. Key challenges for the implementation of D2D applications

D2D applications presents promising opportunities alongside some challenges. Exploring the two variants, D2D-MSS and DC-MSS-IMT, underscores the innovative landscape of satellite and terrestrial communications.

Satellite D2D technology presents promising opportunities and challenges for African Administrations. The D2D-MSS approach generally requires no additional action from national regulators. This approach leverages standardized protocols and frameworks, capitalizing on 3GPP Release 17 Non-Terrestrial Network specifications, to provide seamless connectivity across terrestrial and satellite networks within existing regulatory frameworks. In general, the D2D-MSS approach may rely more on existing MSS regulations while the significant barrier to its use is lack of affordable handsets. Conversely, DC-MSS-IMT is still being studied under WRC-27 agenda item 1.13, but is supported by its use of standard handsets, including affordable devices typically important to many users in ATU countries. Table 2 compares the two D2D variants.

[10] https://www.federalregister.gov/documents/2024/04/30/2024-06669/single-network-future-supplemental-coverage-from-space-space-innovation
[11] https://www.acma.gov.au/publications/2024-09/guide/regulatory-guide-operation-imt-satellite-direct-mobile-service

Table 2: D2D in MSS and IMT frequency bands[17]

D2D-MSS	DC-MSS-IMT
Complement existing terrestrial mobile network coverage	
• Uses spectrum allocated to Mobile Satellite Service	• Uses terrestrial mobile spectrum (IMT frequency bands)
• Requires no additional regulatory action if MSS authorised	• Absence of internationally harmonized regulatory framework • Regulatory hurdles (ITU RR 4.4)
• Some D2D-MSS plan to leverage 3GPP Release 17 NTN frequency bands, whilst existing D2D-MSS utilize proprietary systems using MSS frequency bands	• Uses IMT bands below 3 GHz (WRC-27 A.I. 1.13)
• Requires proprietary user equipment (UE) or off-the-shelf mobile handsets/UE equipped with 3GPP NTN features • Includes MSS delivered to modified smartphone handsets that use a proprietary interface, and which operate on a specific satellite network	• Can use off-the-shelf mobile handsets
• Needs mobile chipset vendors to include NTN bands and NTN functionalities in their handset devices in the case of those D2D-MSS using 3GPP Release 17 NTN specifications	•

4. International experiences: Policy development and licensing/authorization requirements

4.1. D2D-MSS

Regarding D2D-MSS, many administrations around the world authorise MSS in the MSS bands with a general authorisation and related homologation procedures for user equipment, and there is no need for further policy developments or authorizations. In general, ATU needs to examine the specific MSS frequency bands, to provide insights into the potential challenges that may arise when integrating D2D-MSS into existing satellite infrastructure. Nevertheless, ATU administrations may wish to review the current MSS regulations to ensure that D2D-MSS remains feasible within the existing regulatory framework. It is also key to follow discussions on sharing and compatibility that are taking place under WRC-27 AI 1.12, 1.14.

4.2. DC-MSS-IMT

Regarding DC-MSS-IMT, there are already examples of regulatory practices available today. Below is a more detailed treatment of recently implemented practices in the USA, Australia and the European Union (EU) policy development.

i. United States of America[12,13]

On March 14, 2024, the Federal Communications Commission (FCC) adopted a Report and Order and Further Notice of Proposed Rulemaking (Order) adopting new rules governing "**supplemental coverage from space**," or "SCS."

This *Report and Order* would establish a domestic regulatory framework—the first of its kind in the world—to enable collaborations between satellite operators and terrestrial service providers to offer ubiquitous connectivity, directly to consumer handsets using spectrum previously allocated only to terrestrial service. Supplemental Coverage from Space, or SCS, would enable expanded coverage to a terrestrial licensee's subscribers, especially in remote, unserved, and underserved areas, and would increase the availability of emergency communications.

In the Order, the FCC expressed several public interest goals for the SCS framework, including expanding "the reach of communications services, particularly emergency services," into more rural areas, positioning the United States as a global leader in space-based technology, and continuing to "promote the innovative and efficient use" of the spectrum. The Order also reallocates specific spectrum reserved for terrestrial services for use by satellite communications but limits this to "spectrum bands where there are no primary, non-flexible-use legacy incumbent operations, federal or non-federal." The FCC adopted the following bands as eligible for SCS:

1) 600 MHz: 614 - 652 MHz and 663 - 698 MHz;
2) 700 MHz: 698 - 769 MHz, 775 MHz - 799 MHz, and 805 - 806 MHz;
3) 800 MHz: 824 - 849 MHz and 869 - 894 MHz;
4) Broadband PCS: 1850 - 1915 MHz and 1930 - 1995 MHz; and
5) AWS-H Block: 1915 - 1920 MHz and 1995 - 2000 MHz

In brief, the Report and Order:

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[12] FCC Fact Sheet, Single Network Future: Supplemental Coverage from Space Report and Order and Further Notice of Proposed Rulemaking GN Docket No. 23-65 and IB Docket No. 22-271, February 22, 2024 (Retrieved from: https://docs.fcc.gov/public/attachments/DOC-400678A1.pdf)

[13] Retrieved from https://www.pillsburylaw.com/en/news-and-insights/fcc-space-satellite.html#:~:text=On%20March%2014%2C%202024%2C%20the,future%2C"%20fostering%20collaboration%20between%20satellite

1) Adopt a spectrum use framework that enables expanded coverage to a terrestrial licensee's subscribers through a collaboration with a satellite operator through a lease agreement or arrangement.
    - Adopt a secondary, bi-directional, mobile-satellite service (MSS) allocation in specific frequency bands with no primary, non-flexible-use legacy incumbents, federal or non-federal.
    - In certain bands designated for SCS, authorize SCS only where one or more terrestrial licensees— holding all licenses on the relevant channel throughout a defined geographically independent area (GIA)—lease access to the terrestrial spectrum rights to a satellite operator, whose part 25 space station license includes these frequencies and the GIA.
2) Adopt entry criteria that satellite operators must meet to apply for or modify an existing part 25 space station license to operate satellites in SCS bands.
3) Establish a license-by-rule approach for terrestrial devices as SCS earth stations communicating with a satellite network for SCS.
4) Require modified or new equipment authorizations for terrestrial devices and grant a limited waiver of specific equipment authorization rules.
5) Apply—with limited amendments—the existing service rules governing satellite and terrestrial licensees to enable the provision of SCS.
6) Impose technical rules and other recommendations to mitigate potential harmful interference to existing services, including radio astronomy.
7) Clarify international coordination obligations, including outlining steps to ensure that SCS operations will be consistent with relevant ITU Radio Regulations.
8) Adopt interim 911 call and text requirements to route 911 calls and texts to a Public Safety Answering Point using location-based routing or an emergency call center.
9) Clarify that the SCS framework remains separate from the existing framework for MSS systems.

The FCC clarified that its framework will "expand to include additional bands" as the SCS marketplace evolves. The Order also expanded the United States Table of Frequency Allocations (U.S. Table) to permit secondary mobile-satellite service (MSS) operations in the SCS bands. However, as secondary services, these bidirectional MSS operations (space-to-Earth and Earth-to-space) may not cause harmful interference to a primary service in the band, nor are secondary services entitled to interference protection.

The FCC, recognizing that SCS that may occur in bands not allocated for such services in the International Table must be consistent with ITU Radio Regulations No. 4.4, finds that it would serve the public interest to include express conditions in the SCS licenses to ensure that obligations are met as the ITU notifying administration for U.S.-licensed space station operations. In these cases, the FCC will require additional assurances from SCS licensees that while operating outside of the United States, under an authorization from another country, the satellite operations will not cause harmful interference into a nearby country.

Recognizing the complicated task of balancing SCS deployment with the need to minimize the risk of harmful interference, the FCC requires that "a single terrestrial licensee holds all co-channel licenses in the relevant band throughout a geographically independent area (GIA) and the partnering non-geostationary orbit (NGSO) satellite operator holds an existing part 25 license or grant of market access." SCS authorizations are limited to the following GIAs: (1) the contiguous United States (CONUS); (2) Alaska; (3) Hawaii; (4) American Samoa; (5) Puerto Rico/U.S. Virgin Islands; and (6) Guam/Northern Mariana Islands. In addition to authorizing space stations, the FCC must also authorize terrestrial devices communicating with space stations. Under the FCC's rules, any station on Earth that communicates with a space station is considered an earth station, which requires authorization. To authorize earth stations, the FCC has elected a "license by rule" approach in the SCS context.

The Order authorizes SCS based on lease arrangements between terrestrial licensees and satellite operators. Terrestrial licensees may lease access to their frequencies in a particular geographic license area to a satellite operator, allowing the satellite operator to provide supplemental coverage to close gaps in the terrestrial licensee's coverage area. The Order also adopts interim 911 text and call routing requirements for terrestrial providers to use SCS to fill the gaps in their service areas. Terrestrial providers must transmit "all SCS 911 voice calls and texts to a Public Safety Answering Point ... using either an emergency call center or location-based routing". They must transmit location information and the user's phone number.

The FCC adopted a Further Notice of Proposed Rulemaking (FNPRM) in the SCS proceeding. The FNPRM focuses on properly addressing public safety communications using SCS and how best to balance the protection of radio astronomy and space sciences. The FCC seeks comments on how it should handle 911 calls and texts routed through SCS. Finally, the FCC encourages commenters to weigh in on how it should promote and improve the coexistence of radio astronomy and SCS, including what rule changes would be necessary to accomplish its goals.

ii. European Union – Radio Spectrum Policy Group

The European Commission has requested that the Radio Spectrum Policy Group (RSPG) prove an opinion on the EU-level policy approach to satellite Direct-to-Device connectivity and related Single Market Issues. The draft opinion for public consultation is planned for February 2025, with the final opinion due June 2025. The EC notes that D2D is a concept built around two significant solutions of spectrum use by space and terrestrial networks, namely:

1) A frequency band allocated to the mobile service and used for terrestrial systems capable of providing electronic communications services is also used for satellite D2D connectivity without any modification of the mobile terminal, under a partnership model with a holder of rights of use of spectrum within that band in a given country;
2) A frequency band allocated to the satellite service (typically to the mobile satellite service) is used for satellite D2D connectivity to serve modified/adapted mass market mobile terminals.

Regulatory issues related to satellite D2D are being tackled by the European Conference of Postal and Telecommunications Administrations (CEPT) within its FM44 group, and satellite D2D connectivity is addressed at various events like the BEREC workshop on 22 May 2024, the EU has not yet established a common strategy.

While outside the EU, many administrations could subject the access to their market by LEO constellations operated by third-country operators to the compliance with national rules and the ITU Radio Regulations, the EU Member States lack a single market approach.

The RSPG is invited to assess different policy approaches and the need to establish a common EU policy approach for:

1. Satellite D2D connectivity considering, inter alia:
    1) the current ITU (mainly, but not limited to, Article 4.4 of the ITU Radio Regulations) and EU framework;
    2) the national authorisations;
    3) the current/expected use of (potential) frequency bands for satellite D2D connectivity within and outside the EU, and the need for regulatory coordination or technical harmonisation across the EU;
    4) issues related to the handover between non-terrestrial and terrestrial networks;
    5) potential interference issues, including across borders, and possible mitigation measures;
    6) the latest technological developments; and

2. Authorising LEO constellations operated by third countries' operators, considering inter alia:
    1) the current ITU and national frameworks, existing national authorisations and conditions attached thereto;
    2) security and sovereignty issues and other challenges related to the operation of LEO constellations.

Following the above assessment, the RSPG should provide recommendations in line with the EU-level policy priorities on the most appropriate EU-level policy approach, considering the efficient and effective use of the radio spectrum, safeguarding the EU interests, and promoting the development of the EU single market.

iii. Australia

Australia issued a regulatory guide on the operation of an IMT satellite direct-to-device[14] in September 2024. The proposed regulatory framework focuses on DC-MSS-IMT. Some excerpts of this guide are presented below:

[14] Regulatory guide Operation of an IMT satellite direct-to-mobile service.pdf

Spectrum licensing framework
The spectrum of interest for IMT satellite direct-to-mobile services is mainly authorised Australia-wide for use by MNO under spectrum licences. Mobile phones used in an IMT satellite direct-to-mobile service can be operated under the current spectrum licensing framework, subject to the phone complying with all applicable licence conditions, without the need for explicit approval from the Australian Communications and Media Authority (ACMA).

Spectrum licensing and allocations in the Spectrum Plan
The Australian Radiofrequency Spectrum Plan provides that a service operating under a spectrum licence is taken to be considered a primary service unless the spectrum licence specifies that it is a secondary service. This means that operation of a mobile phone under a spectrum licence used in an IMT satellite direct-to-mobile service is consistent with the Spectrum Plan. Currently there are no conditions in existing spectrum licences specifying that Earth or Earth receive services are secondary services. This means that a mobile phone operating under a spectrum licence in relation to an IMT satellite direct-to-mobile service would be doing so as part of a primary service.

Regulatory framework for space objects
Any foreign satellite system proposed for the provision of direct-to-mobile services in Australia would be:

1) operating in outer space;
2) outside the geographic area of Australian spectrum licences held by MNO (see discussion in the following section),
3) currently outside the scope of the Radiocommunications Act 1992 for licensing purposes.

This means that it would operate under the ITU Radio Regulations. As noted above, there is no provision in the Radio Regulations for satellite services to operate in bands utilised by terrestrial mobile broadband services. The rules governing the operation of services in bands for which there is no allocation in the Radio Regulations are contained in Article 4.4.

Geographic area of a spectrum licence and authorisation of devices
The geographic area of an Australian spectrum licence can extend to the limits of the significant portion of the Earth's atmosphere over Australia but does not extend to outer space. Under the Outer Space Treaty, to which Australia is a party, outer space cannot be subject to national appropriation. A mobile phone used in an IMT satellite direct-to-mobile service can be operated within the geographic area of the spectrum licence, provided it operates in accordance with the conditions of the licence. If a terrestrial base station authorised by the licence is not within reach of the phone, the phone's transmissions could be received by a space receive station – unrelated to and not authorised by the spectrum licence – as part of an IMT satellite direct-to-mobile service.

5. Conclusion

D2D-MSS to complement the terrestrial network coverage leverages existing allocations and standardized protocols and frameworks, capitalizing on 3GPP NTN specifications for seamless terrestrial and satellite connectivity networks across various applications.

DC-MSS-IMT provide a quick solution to complement mobile coverage, addressing gaps in connectivity where traditional networks fall short, using off-the-shelf mobile handsets. However, this variant is currently lacking an internationally harmonized ITU framework. Technical and regulatory challenges are been considered to ensure the protection of existing services, both in-band and in adjacent bands. Some countries have adopted national frameworks to enable DC-MSS-IMT services and established rules to protect incumbent services as well as ensure protection of IMT services in neighbouring countries.

Collaboration between Satellite Network Operators (SNO), Mobile Network Operators (MNO), and regulatory bodies is crucial for unlocking the full potential of satellite D2D connectivity and usher in a new era of ubiquitous and seamless communications for Africans. The forthcoming WRC-27 holds pivotal significance for the future of D2D as it will address potential new MSS allocations in Agenda Items 1.13 and 1.14. The regulatory frameworks will also need to address in-country interference, licencing issues, roaming issues, competition issues, cyber-security, and cyber-protection issues.

Regarding DC-MSS-IMT, ATU administrations could, in principle, authorise such operations, subject to addressing a number of technical and regulatory issues. However, given the discussion at the international level (i.e. ITU WRC-27 Agenda item 1.13) it may be preferable to closely follow these discussions to develop possible harmonised regulatory solutions and to observe the deployment models in other parts of the world (i.e. USA, Australia) before engaging on deployment roadmap across ATU member states.

ATU administrations are therefore encouraged to:

1) At the national level, ensure that D2D-MSS remains feasible within the existing regulatory framework that enables today’s MSS services;
2) At the national level, review existing DC-MSS-IMT regulations and consider possible development of ATU regulations similar to those developed by the USA and other countries to enable DC-MSS-IMT;
3) Actively participate in studies related to WRC-27 Agenda Items 1.12, 1.13 and 1.14, to ensure that the regulatory, technical, and operational challenges stemming from the provision of DC-MSS-IMT are understood and mitigated before the development of such services in their Administrations’ territories.

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