Radiocommunication Study Groups

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IAFI[1]

TECHNICAL ASPECTS OF TDD TECHNOLOGY FOR CONNECTIVITY BETWEEN SPACE STATION AND IMT USER EQUIPMENT FOR USE IN THE PROPOSED REPLY LIAISON STATEMENT TO WORKING PARTY 4C REGARDING WRC-27 AGENDA ITEM 1.13

1. Background

WRC-23 approved agenda item 1.13 regarding "direct connectivity between space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage". The CPM27-1 assigned WRC-27 agenda item 1.13 to WP 4C, as the lead responsible group and to working parties including of WP-5D many others as contributing group for sharing their expertise to WP-4C. The CPM27-1 assigned the following tasks to WP 5D:

1. *WP 5D is expected to provide input contributions based on the IMT frequency arrangements contained in the most recent version of Recommendation ITU-R M.1036*
2. *WP 5D is also expected to provide studies which include regulatory considerations on the protection of terrestrial component of IMT*

As a first step, WP-5D sent the following liaison statement to WP-4C on February 12th, 2024.

Regarding 1) above,- it was intimated to WP 4C that IMT frequency arrangements for the frequency range 694/698 MHz - 2.7 GHz are contained in Sections 3 to 7 of latest ITU-R Recommendation ITU-R M.1036-7.

Regarding 2) above, - WP 5D would appreciate receiving the MSS system description and functionality, including frequency bands considered for Earth-space and space-Earth operation. This information would enable WP 5D to provide WP 4C, information on the sharing scenarios necessary for assessing the impact to IMT terrestrial systems.

[1] IAFI (ITU-APT Foundation of India) is a sector member of ITU-R

Working Party 5D seeks confirmation of WP 4C on the understanding in WP 5D that the planned MSS operations would conform to the directionality of the terrestrial frequency arrangements as defined in Recommendation ITU-R M.1036. It is worth mentioning that neighbouring administrations may operate different frequency arrangements (e.g. FDD and/or TDD) for the terrestrial component of IMT, so this should be taken into account when performing the sharing and compatibility studies and the studies to protect the terrestrial component of IMT.

Reply liaison statement from WP-4C

WP-4C responded to WP-5D's liaison statement (C-107) on May 1st, 2024, with the following reply:

> *WP 4C would like to confirm that IMT frequency arrangements for the frequency range 694/698 MHz – 2.7 GHz in Recommendation ITU R M.1036-7 should be used for the sharing and compatibility studies under WRC-27 agenda item 1.13. In addition, studies for WRC-27 agenda item 1.13 should be consistent with the directionality and pairing of the terrestrial frequency arrangements as defined in Recommendation ITU-R M.1036-7 for the paired arrangements frequency division duplex (FDD) frequency bands, noting that neighbouring administrations may operate different frequency arrangements than the ones contained in Recommendation ITU-R M.1036 (e.g. FDD and/or TDD) for the terrestrial component of IMT. In this case, the envisaged operations for these types of satellite networks would conform to the directionalities of the Recommendation ITU-R M.1036 frequency arrangements allowed in the country of operation. This will be taken into account when performing the sharing and compatibility studies to protect the terrestrial component of IMT.*
>
> *WP-4C further intimated that the use of TDD frequency arrangements for these types of satellite networks is still under discussion.* ***Therefore, WP 5D is requested to provide its view on the technical aspects with regards to the use and operation of TDD for direct connectivity between space stations and IMT user equipment****.*
>
> *WP-4C also intimated that the preliminary frequency band list for these envisaged satellite systems would include the following frequency bands (or parts thereof): 694/698-960 MHz, 1 427-1 518 MHz, 1 710-1 785 MHz, 1 805-2 025 MHz, 2 110-2 200 MHz, 2 300-2 400 MHz, 2 500-2 690 MHz. The list will be finalized at the October 2024 meeting of WP 4C.*

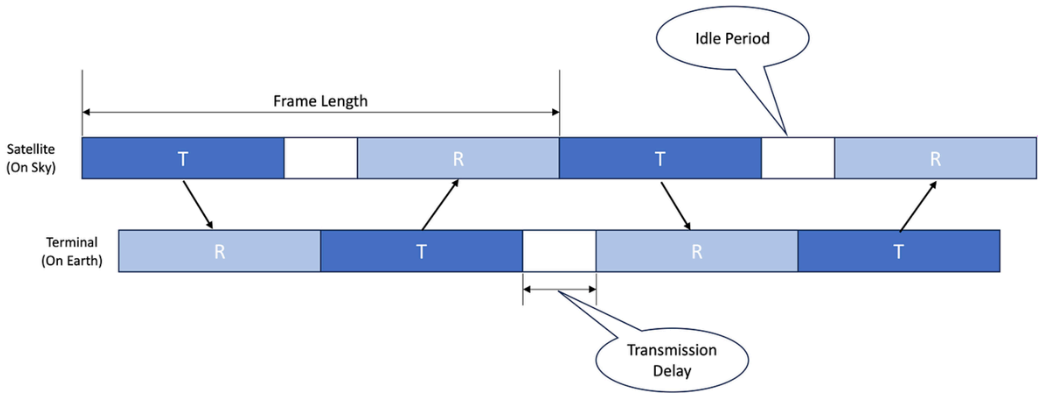
Finally, WP-4C requested WP-5D to provide the views on the technical aspect to use and operate TDD connectivity between space station and IMT user equipment.

This contribution provides some technical aspect regarding use of TDD connectivity between space station and IMT user equipment.

2. Technical aspects of use of TDD connectivity between space stations and IMT user equipment[2].

[2] Refer https://open.substack.com/pub/paragkar/p/why-are-satellite-bands-always-fdd?utm_campaign=post&utm_medium=web

2.1 Let's assume a TDD frame for a MSS satellite system looks something like this.



The row on the top of the figure is the frame that is linked to the MSS satellite that is located up in the orbit. Here "T" represents the period where the MSS satellite is transmitting and "R" is the portion of the frame where the satellite is receiving. The period between these two blocks sandwiches an idle period when the satellite is doing nothing because this is the time the RF signal takes to reach the terminal located on the ground, and its transmission reaching back to the satellite.

2.2 Idle Period Value

In order to calculate the value of the idle period, let's say the satellite is located 500 Km up in the sky, then the round-trip distance between the satellite and the ground terminal will be 1000 Km. Using simple math we have:- Distance = Speed x Time. Which means Time = Distance /Speed. Now Distance = 1000 Kms, and Speed = 3,00,000 Kms/sec (speed of light**).** Hence round trip delay for the RF wave for traveling a distance of 1000 km will be = 1000/3,00,000 = 3.33 milliseconds. The following table lists the round-trip delays for satellites located at various heights above the ground and its corresponding delays, assuming that the satellite is transmitting to the IMT terminal directly below the satellite.

1	2	3	4	5	6	7
S.No	Satellite Height (Kms)	Round Trip Distance (Kms)	Idle Period (Milliseconds)	Frame Size (Millisecond)	Data Efficiency %	Total Latency (Milliseconds)
1	500	1000	3.33	10	66.67%	6.67
2	700	1400	4.67	10	53.33%	7.33
3	900	1800	6.00	10	40.00%	8.00
4	1100	2200	7.33	15	51.11%	11.17
5	1300	2600	8.67	15	42.22%	11.83
6	1500	3000	10.00	15	33.33%	12.50
7	1700	3400	11.33	20	43.33%	15.67
8	1900	3800	12.67	20	36.67%	16.33
9	2100	4200	14.00	20	30.00%	17.00
10	2300	4600	15.33	30	48.89%	22.67
11	2500	5000	16.67	30	44.44%	23.33
12	2700	5400	18.00	30	40.00%	24.00
13	2900	5800	19.33	35	44.76%	27.17
14	3100	6200	20.67	35	40.95%	27.83
15	3300	6600	22.00	35	37.14%	28.50
16	36000	72000	240.00	500	52.00%	370.00

2.3 Data Efficiency

In order to calculate the efficiency of the overall system (Column No.6) for a particular frame size, the formula is = Transmitted Time (both UL & DL) / Frame Size**.** As an example, for the row marked with the serial number 4 in the table above, the Frame Size as 15 ms, and the corresponding idle period is 15-7.33 = 7.67 ms. Hence, the efficiency of the overall system will become = 7.67/15 = 51.11 %.

Note that in order to increase the efficiency of the system to a higher number, we have to increase the frame size, but that will also increase the latency of the overall system.

2.4 Total Latency

The formula to calculate the latency of the overall system, assuming that the uplink and downlink are of the same duration their respective time in milliseconds, will become = (Frame Size - Idle Period)/2. Now to this value, we need to add the Idle Period to get the overall system latency.

Therefore, the system latency is directly linked to the Frame Size. The higher the value of frame size, more will be the latency and since the Idle Period is also getting added, its value will also increase with the height of the satellite as well.

2.5 The FDD Mode

Now if the satellite operators are in the FDD mode then the idle item can be avoided due to the possibility of simultaneous data transmission in both the links (transmit and receive) independently. But it still has to deal with a major issue. That is if the system asks for the retransmission of packets due to losses in between then such a request can be very costly due to the inherent round-trip delay.

This puts a lot of pressure on the coding of data for satellites, as the system needs to ensure accurate carriage of packets each and every time a transmission is made to prevent undue increase in latency**.** This is quite unlike the terrestrial case where the retransmission of packets will not add to a huge increase in latency due to the shorter distance of the UE from the BTS.

2.6 Comparison of Interference from MSS in FDD and TDD frequency arrangements

MSS systems based on FDD are likely to experience less interference than the MSS systems based on **TDD**, due to the following reasons:

a. Separate Frequency Bands for uplink and downlink**:** FDD systems use separate frequency bands for uplink and downlink transmissions. This means that there is no potential for self-interference within the IMT system itself, and the filters can be designed to specifically reject the MSS signals in the downlink band and vice-versa.

b. Continuous Transmission**:** In FDD, both uplink and downlink transmissions are continuous. This means that the receiver is constantly receiving the desired signal, making it more robust to interference from MSS signals, which are typically intermittent or bursty in nature.

c. Simpler Filtering**:** Since FDD systems use separate frequency bands, the filtering requirements are simpler. The filters only need to isolate the desired signal from the MSS signal in the corresponding frequency band.

On the other hand, **TDD** systems are more susceptible to interference from MSS because:

a. Shared Frequency Band**:** TDD systems use the same frequency band for both uplink and downlink transmissions, alternating between them in time. This means that there is a potential for self-interference within the IMT system, and the filters need to be more complex to accommodate both uplink and downlink frequencies.

b. Discontinuous Transmission**:** In TDD, the uplink and downlink transmissions are not continuous. This means that the receiver is not always receiving the desired signal, making it more vulnerable to interference from MSS signals during the silent periods.

c. More Complex Filtering**:** The filtering requirements for TDD systems are more complex due to the shared frequency band. The filters need to be able to switch between uplink and downlink frequencies, and they also need to reject MSS signals in both bands.

Proposal

While IAFI is not proposing to take a view for or against the TDD at this moment, it is proposed that the above information may be suitably included in the proposed reply liaison statement to WP4C. WP4C needs to take into account the complexities and challenges of using TDD technology while considering direct connectivity between MSS space stations and International Mobile Telecommunications (IMT) user equipment to complement terrestrial IMT network coverage.