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Dynamic spectrum sharing and bandwidth-efficient techniques for high-throughput MIMO Satellite systems

D3.5: Bandwidth Efficient Techniques evaluation (version 2)

Revision: v.1.1

Work package	WP3
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Abstract

This deliverable is a second interim version of the outcomes of Task 3.3 “Bandwidth efficient techniques for satellite network performance evaluation.” Based on the outcomes of the first analyses reported in the companion document D3.4: i) for MU-MIMO, both Earth fixed and Earth moving beams were considered with one and multiple satellites and implementing both CSI- and location-based beamforming techniques; and ii) Multi-Connectivity was evaluated with two satellites, each generating seven beams, and traffic steering algorithms were also alaysed.

Keywords: Non-Terrestrial Networks, Beamforming, MU-MIMO, spectrum sharing, NTN services, 3GPP

Document Revision History

Version	Date	Description of change	List of contributor(s)
V0.1	10/04/2022	Document creation	UNIBO
V0.2	25/04/2022	First draft version with enhanced MU-MIMO simulator	UNIBO/UNIPR/TASF
V0.3	28/04/2022	Refined MC scenario results and calibration results annex	Mikko Majamaa and Henrik Martikainen MAG
V0.4	13/05/2022	First version for internal revision	UNIBO/UNIPR/TASF/MAG
V0.5	20/05/2022	Second version based on the received internal feedback	UNIBO/UNIPR/TASF/MAG
V1.0	22/05/2022	First release for submission to the SAB	UNIBO
V1.1	30/11/2022	Typos corrected	UNIBO

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Nature of the deliverable:	R	
Dissemination Level		
PU	Public, fully open, e.g., web	√
CI	Classified, information as referred to in Commission Decision 2001/844/EC	
CO	Confidential to DYNASAT project and Commission Services	

* *R: Document, report (excluding the periodic and final reports)*
DEM: Demonstrator, pilot, prototype, plan designs
DEC: Websites, patents filing, press & media actions, videos, etc.
OTHER: Software, technical diagram, etc

EXECUTIVE SUMMARY

Task 3.3 is aimed at assessing the performance of the techniques selected from D3.1 and designed in the companion document D3.2 in the DYNASAT mega-constellation. This second version of the task outcomes builds on the previous document D3.4 and introduces several enhancements and additional analyses. In particular:

- Multi-User Multiple Input Multiple Output (MU-MIMO) techniques
  - In 3GPP nomenclature, the two following scenarios are considered: i) Earth fixed beams, in which the satellites cover a fixed on-ground service area independently from their location on the orbit by digitally steering the beams; and ii) Earth moving beams, in which the satellites always cover a service area centered at their corresponding SSP, which moves with the satellites revolution along their orbit.
  - Both single and multiple satellites scenarios are considered. In the Earth fixed beams case, both solutions cover the same on-ground.
  - The following techniques have been implemented:
    - Minimum Mean Square Error (MMSE): upper performance bound for the algorithms proposed in this work and described in D3.2 and D3.5.
    - Multi-Beam (MB): location-based phase-only beamforming technique, equivalent to a beam space non-precoded system. This technique, available in the literature, is considered as the lower performance bound.
    - Spatially-Sampled MMSE (SS-MMSE): location-based technique designed in WP3 based on approximating each user with the closest beam center position and on computing the beamforming matrix based on such information.
    - Location-Based MMSE (LB-MMSE): similar to SS-MMSE, but without approximating the users' locations with the closest beam center. This technique is assessed for the first time in this document.
  - The on-ground users can be fixed or moving according to the user terminal scenarios described in 3GPP TS 22.261 and TR 38.821. The system parameters are aligned with the specifications provided in TR 38.821 and TR 38.811. The on-board antenna is defined in ITU-R Recommendation M.2101 and in the DYNASAT Technical Note on "Satellite Antenna Model."
  - In order to better compare the single and multiple satellite scenarios, the outage probability has been introduced as an additional KPI. To this aim, the spectral efficiency that is reported in the numerical assessment is that of the UEs that are served with an SINR above the minimum SINR threshold provided by 3GPP.

  Finally, it is worthwhile highlighting that only feed space solutions, *i.e.*, user-centric (or Cell-Free, CF) MIMO, are considered. This is motivated by observing that beam space precoding is always providing a worse performance compared to feed space solutions.
- Multi-Connectivity (MC) techniques
  - Both inter-beam single satellite NTN-NTN MC and inter-satellite NTN-NTN MC candidate scenarios with LEO satellites and stationary (non-mobile) UEs available.
  - Priority for NTN-NTN MC (no TN-NTN) asynchronous MC.
  - MC is assumed to use different frequency bands.
  - MC evaluated with an identified candidate scenario which includes two satellites with seven beams each. Developed Secondary Node (SN) addition algorithm and MC related traffic steering algorithms are tested and analysed.

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ABBREVIATIONS

3GPP	Third Generation Partnership Project
BER	Bit error rate
BLER	Block error rate
CDF	Cumulative Distribution Function
CL	Clutter Loss
CPC	Centralised Precoding Computation
CPE	Common phase error
CRC	Cyclic redundancy check
CSI	Channel State Information
DCI	Downlink control information
DLSCH	Downlink shared channel
DMRS	Demodulation reference signal
DPC	Distributed Precoding Computation
ECEF	Earth-Centered Earth-Fixed
eMBB	enhanced Mobile Broadband
FFR	Full Frequency Reuse
FoV	Field of View
gNB-CU	gNB Centralised Unit
gNB-DU	gNB Distributed Unit
HARQ	Hybrid automatic repeat request
IMUX	Input Multiplexer
INR	Interference-to-Noise Ratio
ISL	Inter Satellite Link
ITU-R	International Telecommunication Union – Radiocommunication sector
LB-MMSE	Location Based MMSE
LDPC	Low density parity check
LEO	Low Earth Orbit
LOS	Line-of-Sight
KPI	Key Performance Indicator
MB	Multi-Beam
MC	Multi-Connectivity
MIMO	Multiple Input Multiple Output
MMSE	Minimum Mean Square Error
MU-MIMO	Multi User MIMO
MN	Master Node
MPC	Maximum Power Constraint
NCC	Network Control Center

NLOS	Non-Line-Of-Sight
NR	New Radio
NTN	Non-Terrestrial Network
OFDM	Orthogonal frequency division multiplexing
OMUX	Output Multiplexer
PAC	Per Antenna Constraint
PCID	Physical Cell ID
PDSCH	Physical downlink shared channel
PHY	Physical layer
pLOS	pure LOS
PoC	Proof of Concept
PRACH	Physical random access channel
PTRS	Phase tracking reference signal
PUSCH	Physical uplink shared channel
RRM	Radio Resource Management
RTT	Round Trip Time
SINR	Signal-to-Interference-plus-Noise Ratio
SIR	Signal-to-Interference Ratio
SLS	System Level Simulator
SN	Secondary Node
SNR	Signal-to-Noise Ratio
sMPC	satellite MPC
SPC	Sum Power Constraint
SSB	Signal synchronization block
SS-MMSE	Spatially Sampled MMSE
SSP	Sub Satellite Point
SSPA	Solid state power amplifier
sSPC	satellite SPC
TN	Terrestrial Network
TR	Technical Report
TS	Technical Specification
UDP	User Datagram Protocol
UE	User Equipment
ULSCH	Uplink shared channel
VSAT	Very Small Aperture Terminal

1 INTRODUCTION

[REDACTED according to the Security Advisory Board Indications]

2 MU-MIMO TECHNIQUES: SIMULATOR DESCRIPTION AND PRELIMINARY NUMERICAL ASSESSMENT

[REDACTED according to the Security Advisory Board Indications]

3 MU-MIMO: REFINED SCENARIO AND PERFORMANCE EVALUATION

[REDACTED according to the Security Advisory Board Indications]

4 MULTI-CONNECTIVITY TECHNIQUES: PRELIMINARY RESULTS

[REDACTED according to the Security Advisory Board Indications]

5 CONCLUSIONS

[REDACTED according to the Security Advisory Board Indications]

6 ANNEX A: LINK-LEVEL SIMULATOR

[REDACTED according to the Security Advisory Board Indications]

7 ANNEX B: CALIBRATION SIMULATION RESULTS

[REDACTED according to the Security Advisory Board Indications]

REFERENCES