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| **Radiocommunication Study Groups** |  |
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| **English only**  **TECHNOLOGY ASPECTS** |
| Director, Radiocommunication Bureau[[1]](#footnote-1) | |
| Final EVALUATION REPORT FROM AEG FOR TSDSI PROPONENT SUBMISSIONS OF RIT | |
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# 1 Introduction

In accordance to the ITU-R Submission, Evaluation Process and Consensus Building for IMT-2020 (Doc. [IMT-2020/2](https://www.itu.int/md/R15-IMT.2020-C-0002/en)), the Africa Evaluation Group (AEG) has been established as an independent evaluation group open to all African administrations, industry and academia.

At the 33rd WP 5D, AEG did not provide evaluation for TSDSI, due to time constraints and to ensure that the evaluation work does not get delayed, the AEG had to focus on the “simulation approach” for submission of TSDSI RIT [1]. This report focuses on evaluation of the (1) *5th percentile user spectral efficiency*, and (2) *average spectral efficiency.*

This submission covers items labelled “Simulation” in Table 1 *“Summary of evaluation methodologies*” of ITU-R M.2412-0. The assessment criteria from Reports ITU-R M.2410-0 (11/2017), ITU-R M.2411-0 (11/2017) and ITU-R M.2412-0 (10/2017) have been followed.

NB: The simulation analysis of the TSDSI RIT is compared with 3GPP RIT throughout this report.

# 2 Evaluation of Technical Performance Requirements (TPR)

This section evaluates TPR of the TSDSI submission for IMT-2020.

## 2.1 5th percentile user spectral efficiency

As defined in Report ITU-R M.2410-0, the 5th percentile user spectral efficiency is the 5% point of the cumulative distribution function (CDF) of the normalized user throughput. The normalized user throughput is defined as the number of correctly received bits, i.e. the number of bits contained in the service data units (SDUs) delivered to Layer 3, over a certain period of time, divided by the channel bandwidth and is measured in bit/s/Hz.

The channel bandwidth for this purpose is defined as the effective bandwidth times the frequency reuse factor, where the effective bandwidth is the operating bandwidth normalized appropriately considering the uplink/downlink ratio.

As required by Report ITU-R M.2412-0, 5th percentile user spectral efficiency shall be assessed jointly with average spectral efficiency using the same simulation. Therefore, the evaluation results of the 5th percentile user spectral efficiency are provided together with average spectral efficiency in 2.2 below.

## 2.2 Average spectral efficiency

As defined in Report ITU-R M.2410-0, average spectral efficiency is the aggregate throughput of all users (the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time) divided by the channel bandwidth of a specific band divided by the number of TRxPs and is measured in bit/s/Hz/TRxP.

The evaluation of the average spectral efficiency is conducted for the two different test environments of Dense Urban – eMBB and Rural – eMBB. The test environments and evaluation configuration parameters are described in Report ITU-R M.2412-0. Further evaluation assumptions can be found in Annex A.

### 2.2.1 Technical features for TSDSI

According to TSDSI RIT in [1], the new technology features different from 3GPP RIT are summarized as follows:.

* ***Feature 1:*** *The configuration of resource block group (RBG) size is not determined by bandwidth part size (BWP) size. For 3GPP specification [2], the RBG size is determined by BWP size.*
* ***Feature 2****: Shorter processing time between NZP-CSI-RS and aperiodic SRS is supported, as defined in Table 1. For 3GPP specification [2], the delay is 42 symbols.*

Table 1

The delay configuration for SRS precoding

|  |  |
| --- | --- |
| μ (Numerology) | Delay in number of OFDM symbols |
| 0 | 4 |
| 1 | 7 |
| 2 | 14 |
| 3 | 29 |

* ***Feature 3:*** *Mandating pi/2 BPSK with spectrum shaping filter and mandating 26 dBm for Pi/2 BPSK. Configurable Tx power for DMRS and data when Pi/2 BPSK is used.*
* ***Feature 4:*** *Provide additional phase tracking reference signal (PTRS) density determination.*

NB: If the above features in the TSDSI RIT are not applied, the evaluation results would be the same as that submitted by 3GPP

In the following sub-sections, the potential performance gain for the above technical features except PTRS enhancement will be evaluated. In sub-6 GHz, PTRS is usually not configured. All PRTS density configurations allowed by TSDSI are also allowed by 3GPP specification, thus no PTRS overhead saving can be achieved by TSDSI compared to 3GPP.

### 2.2.2 Evaluation results

The performance of RBG size configuration and fast SRS precoding is evaluated in Dense Urban – eMBB test environment. For the transmission power enhancement with pi/2 BPSK, the performance is evaluated in Rural – eMBB test environment, to identify the gain for coverage enhancement. The test environments and evaluation configuration parameters are described in Report ITU-R M.2412‑0. Further evaluation assumptions can be found in Annex A.

#### 2.2.1.1 Dense Urban - eMBB

Configuration A (carrier frequency of 4 GHz) and channel model A are applied for the Dense Urban – eMBB test environment.

In the evaluation, the simulation bandwidth is assumed to be 20 MHz. For 3GPP specification [2], the RBG size depending on the bandwidth part size (i.e. 20MHz in the evaluation) can be 4 or 8 PRBs. For TSDSI, the configuration of RBG size is decoupled by bandwidth part size. To differ from 3GPP, the RBG size is set to 16 PRBs in the evaluation. The downlink evaluation results for different RBG size are provided in Table 2. The overhead of control channel for large RBG size is lower than that of small RBG size. However, the performance of average and 5%-percentile spectral efficiency is degraded due to the decline of frequency-selective gain.

Table 2

Spectral efficiency ([bit/s/Hz/TRxP]) in Dense Urban – eMBB

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Scheme and antenna configuration | Sub-carrier spacing (kHz) | Frame structure | RBG size | RIT | ITU  Requirement | | 20 MHz bandwidth |
| 32x4 adaptive SU/MU -MIMO | 30 kHz | DDDSU | 4 | 3GPP NR | Average [bit/s/Hz/TRxP] | 7.8 | 12.66 |
| 5th-percentile [bit/s/Hz] | 0.225 | 0.37 |
| 32x4 adaptive SU/MU -MIMO | 30 kHz | DDDSU | 8 | 3GPP NR | Average [bit/s/Hz/TRxP] | 7.8 | 11.9 |
| 5th-percentile [bit/s/Hz] | 0.225 | 0.35 |
| 32x4 adaptive SU/MU -MIMO | 30 kHz | DDDSU | 16 | TSDSI | Average [bit/s/Hz/TRxP] | 7.8 | 11.15 |
| 5th-percentile [bit/s/Hz] | 0.225 | 0.34 |

It is observed that the downlink average and 5%-percentile spectral efficiency is declined when the RBG size configuration for TSDSI is used.

Similar to downlink evaluation, the uplink evaluation results for different RBG size are provided in Table 3.

Table 3

Uplink spectral efficiency for TSDSI in Dense Urban – eMBB

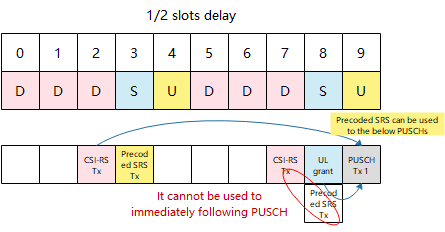
|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Scheme and antenna configuration | Sub-carrier spacing (kHz) | Frame structure | RBG size | RIT | ITU  Requirement | | 20 MHz bandwidth |
| 2x32 SU-MIMO | 30 kHz | DDDSU | 4 | 3GPP NR | Average [bit/s/Hz/TRxP] | 5.4 | 6.94 |
| 5th-percentile [bit/s/Hz] | 0.15 | 0.34 |
| 2x32 SU-MIMO | 30 kHz | DDDSU | 8 | 3GPP NR | Average [bit/s/Hz/TRxP] | 5.4 | 6.53 |
| 5th- percentile [bit/s/Hz] | 0.15 | 0.33 |
| 2x32 SU-MIMO | 30 kHz | DDDSU | 16 | TSDSI | Average [bit/s/Hz/TRxP] | 5.4 | 5.98 |
| 5th- percentile [bit/s/Hz] | 0.15 | 0.29 |

For precoded SRS transmission, the delay between CSI-RS measurement and precoded SRS transmission is defined as 42 OFDM symbols for 3GPP NR. For TSDSI, shorter processing delay between CSI-RS measurement and precoded SRS transmission is supported for uplink non-codebook transmission in TDD mode. The performance enhancement comes from the accurate precoder applied for PUSCH transmission. However, the delay between CSI-RS measurement and PUSCH transmission not only depends on the transmission time of precoded SRS but also depends on the transmission time of PUSCH. In the following, the impacts of delay on CSI-RS measurement, precoded SRS transmission, and PUSCH transmission are analyzed in Figure 1.

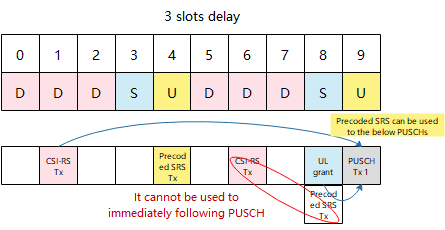
In Figure 1, the frame structure ‘DDDSU’ is applied for the analysis and the scheduling delay is assumed to be one slot (including 14 OFDM symbols for one slot). In Figure 1-(a), the CSI-RS is transmitted in slot 2 and the precoded SRS can be transmitted in slot 3 or slot 4. One or 2 slots delay exist between CSI-RS measurement and precoded SRS transmission. Due to the scheduling delay and uplink grant transmission, the following PUSCH cannot use the channel state information derived from the precoded SRS in slot 3. As a result, the PUSCH transmission in slot 9 would use the precoder measured in slot 2. 3 slots delay between CSI-RS measurement and precoded SRS transmission is assumed in Figure 1-(b). The PUSCH transmission in slot 9 would use the precoder measured in slot 1. It can be observed that the total delay between CSI-RS measurement and the corresponding PUSCH transmission is much larger than that of SRS precoding delay. The performance is limited by the total delay rather than the SRS precoding delay.

Figure 1

Delay analysis for CSI-RS measurement, precoded SRS and PUSCH transmission



1. 1 or 2 slots delay between CSI-RS measurement and precoded SRS transmission



1. 3 slots delay between CSI-RS measurement and precoded SRS transmission

The evaluation results are provided in Table 4. It can be observed that there is little impact on spectral efficiency for the delay reduction of precoded SRS. Although the delay between CSI-RS measurement and precoded SRS transmission is reduced, the delay between CSI-RS measurement and PUSCH transmission is also very large. The delay analysis can be found in Figure 1. Additionally, only the wideband precoder for SRS is supported by 3GPP NR and TSDSI. The channel for wideband changes slowly so that the performance is not sensitive to delay reduction.

Table 4

UL spectral efficiency for fast SRS precoding (TSDSI) in Dense Urban – eMBB

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Scheme and antenna configuration | Sub-carrier spacing (kHz) | Frame structure | Delay for SRS precoding | RIT | ITU  Requirement | | 20 MHz bandwidth |
| 2x8 SU-MIMO | 30 | DDDSU | 1 or 2 slots | TSDSI | Average [bit/s/Hz/TRxP] | 5.4 | 7.038 |
| 5th-percentile [bit/s/Hz] | 0.15 | 0.42 |
| 2x8 SU-MIMO | 30 | DDDSU | 3 slots | 3GPP NR | Average [bit/s/Hz/TRxP] | 5.4 | 7.036 |
| 5th-percentile [bit/s/Hz] | 0.15 | 0.418 |

Based on the above analysis and the evaluation results, it is observed that there is little impact on spectral efficiency improvement for the delay reduction of precoded SRS.

#### 2.2.1.1 Rural - eMBB

For TSDSI, pi/2 BPSK with spectrum shaping filter through non-transparent approach is introduced to improve the coverage in Rural scenario, especially for the coverage of long distance. In [1], the inter-site distance (ISD) is set to 12 km for pi/2 BPSK evaluation. But the largest inter-site distance is 6 km defined in Rural – eMBB test environment [3]. To identify the performance gain of pi/2 BPSK, the Rural configuration C – eMBB test environment with 6 km is evaluated. For the coverage of long distance, the configuration C with changed inter-site distance and carrier frequency (CF) is applied for the evaluation.

In the evaluation, the maximal transmit power for UE can achieve 26 dBm if pi/2 BPSK is enabled. Otherwise, the maximal transmit power is up to 23 dBm.

The uplink evaluation results for evaluation configuration C are provided in Table 5. For ISD = 6 km, the 5%-tile spectral efficiency can meet the requirements with and without pi/2 BPSK. The performance gain for pi/2 BPSK is very small. When the coverage is not limited, the probability to select pi/2 BPSK is very slow since the SINR is higher than the threshold of selecting pi/2 BPSK.

Table 5

UL spectral efficiency for pi/2 BPSK (TSDSI) in Rural - eMBB  
(Evaluation configuration C with ISD = 6 km and CF = 700 MHz)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Scheme and antenna configuration | Sub-carrier spacing (kHz) | Frame structure | UE transmit power | ITU  Requirement | | 10 MHz bandwidth |
| 2x8 SU-MIMO | 15 | FDD | 23 dBm without pi/2 BPSK | Average [bit/s/Hz/TRxP] | 1.6 | 4.15 |
| 5th-tile [bit/s/Hz] | 0.045 | 0.093 |
| 2x8 SU-MIMO | 15 | FDD | 26 dBm with pi/2 BPSK | Average [bit/s/Hz/TRxP] | 1.6 | 4.04 |
| 5th-tile [bit/s/Hz] | 0.045 | 0.10 |

For the coverage of long distance, the configuration C with changed inter-site distance and carrier frequency is evaluated, i.e. ISD = 12 km and CF = 4 GHz. The evaluation results are provided in Table 6. It is observed that the 5%-tile spectral efficiency with and without pi/2 BPSK is equal to 0. There is no coverage enhancement for pi/2 BPSK. In addition, the cumulative distribution function (CDF) of throughput is illustrated in Figure 2. It is observed that there is a large gap to coverage the cell-edge users due to the high path loss.

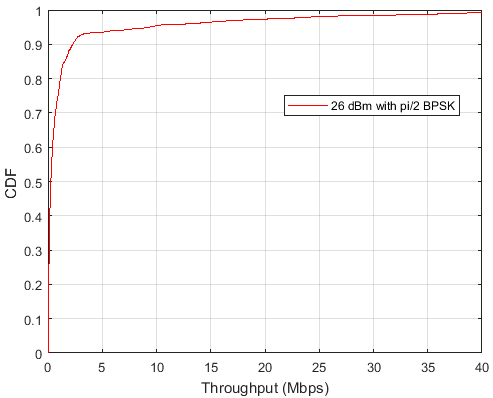
Table 6

UL spectral efficiency for pi/2 BPSK (TSDSI) in Rural - eMBB  
(Changed evaluation configuration C with ISD = 12 km and CF = 4 GHz)

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Scheme and antenna configuration | Sub-carrier spacing (kHz) | Frame structure | UE transmit power | ITU  Requirement | | Channel model A |
| BW=20 MHz |
| 2x8 SU-MIMO | 30 | DDDSU | 23 dBm without pi/2 BPSK | Average [bit/s/Hz/TRxP] | 1.6 | 1.77 |
| 5th-tile [bit/s/Hz] | 0.045 | 0.0 |
| 2x8 SU-MIMO | 30 | DDDSU | 26 dBm with pi/2 BPSK | Average [bit/s/Hz/TRxP] | 1.6 | 1.80 |
| 5th-tile [bit/s/Hz] | 0.045 | 0.0 |

Figure 2

CDF of throughput for pi/2 BPSK



### 2.2.3 Summary

The summary of the evaluation results for TSDSI RIT are provided. The performance comparison between TSDSI and 3GPP can be found in the following table.

| Minimum technical performance requirements item (5.2.4.3.x), units, and Report ITU-R M.2410-0 section reference(1) | Category | | | Required value | TSDSI Value(2) | 3GPP Value(2) | Requirement met? | Comments(3) |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Usage scenario | Test environment | Downlink or uplink |  |  |  |  |  |
| **5.2.4.3.4** 5th percentile user spectral efficiency (bit/s/Hz) *(4.4)* | eMBB | Dense Urban – eMBB | Downlink | 0.225 | 0.34~0.37 | 0.35~0.37 | Yes | Configuration A is evaluated. The performance of TSDSI is slightly lower than that of 3GPP. |
| Uplink | 0.15 | 0.29~0.42 | 0.33~0.418 | Yes |
| eMBB | Rural - eMBB | Uplink | 0.045 | 0~0.10 | 0~0.093 | Yes | Configuration C with changed inter-site distance and carrier frequency is evaluated. TSDSI cannot improve the coverage compare to 3GPP. |
| **5.2.4.3.5** Average spectral efficiency (bit/s/Hz/ TRxP) *(4.5)* | eMBB | Dense Urban – eMBB | Downlink | 7.8 | 11.15~12.66 | 11.9~12.66 | Yes | Configuration A is evaluated. The performance of TSDSI is lower than that of 3GPP. |
| Uplink | 5.4 | 5.98~7.038 | 6.53~7.036 | Yes |
| eMBB | Rural – eMBB | Uplink | 1.6 | 1.80~4.04 | 1.77~4.15 | Yes | Configuration C with changed inter-site distance and carrier frequency is evaluated. The performance for TSDSI and 3GPP is similar. |
| (1) As defined in Report ITU-R M.2410-0.  (2) According to the evaluation methodology specified in Report ITU-R M.2412-0.  (3) Proponents should report their selected evaluation methodology of the Connection density, the channel model variant used, and evaluation configuration(s) with their exact values (e.g. antenna element number, bandwidth, etc.) per test environment, and could provide other relevant information as well. For details, refer to Report ITU-R M.2412-0, in particular, § 7.1.3 for the evaluation methodologies, § 8.4 for the evaluation configurations per each test environment, and Annex 1 on the channel model variants.  (4) Refer to § 7.3.1 of Report ITU-R M.2412-0. | | | | | | | | |

## 2.3 Conclusions

The assessment and evaluation results for TSDSI RIT [1] are provided in this report to identify the performance gain comparing to 3GPP NR. The following observations can be obtained.

* For the evaluation of RBG size configuration, the average spectral efficiency and 5% user spectral efficiency of TSDSI are slightly lower than that of 3GPP in configuration A of Dense Urban - eMBB test environment.
* For the evaluation of fast SRS precoding, there is not much gain for TSDSI compared that of 3GPP in configuration A of Dense Urban - eMBB test environment.
* For the evaluation of pi/2 BPSK with transmit power enhancement, the coverage could not be improved in the configuration C for long distance.

Annex A

Evaluation assumptions for spectral efficiency

The detailed evaluation assumptions for downlink and uplink are illustrated in Table A-1 and Table A-2, respectively.

Table A-1

Evaluation assumptions for downlink

|  |  |
| --- | --- |
| Configuration parameters | Dense Urban (Configuration A) |
| Multiple access | OFDMA |
| Duplexing | TDD |
| Network synchronization | Synchronized |
| Carrier frequency | For configuration A: 4GHz |
| Modulation | Up to 256 QAM |
| Coding on data channel | LDPC |
| Subcarrier spacing | 30 kHz |
| Simulation bandwidth | 20MHz |
| Frame structure | DDDSU |
| Transmission scheme | Adaptive SU/MU-MIMO |
| MU dimension | Up to 12 layers |
| SU dimension | Up to 4 layers |
| Codeword (CW)-to-layer mapping | For 1~4 layers, CW1; For 5 layers or more, two CWs |
| CSI feedback | every 5ms |
| Interference measurement | SU-CQI |
| ACK/NACK delay | The next available UL slot |
| Antenna configuration at TRxP | For 32T: (M,N,P,Mg,Ng; Mp,Np) = (8,8,2,1,1;2,8)  (dH, dV) = (0.5, 0.8) λ |
| Antenna configuration at UE | For 4R: (M,N,P,Mg,Ng; Mp,Np)= (1,2,2,1,1; 1,2)  (dH, dV) = (0.5, N/A) λ |
| Scheduling | PF |
| Receiver | MMSE-IRC |
| Channel estimation | Non-ideal |
| TRxP number per site | 3 |
| Mechanic tilt | 90° in GCS |
| Electronic tilt | 105° in LCS |
| Handover margin (dB) | 1 |
| Wrapping around method | Geographical distance-based wrapping |
| Criteria for selection for serving TRxP | RSRP based |
| Overhead | PDCCH: 2 complete symbols  DMRS: Type II, based on MU-layer (dynamic in simulation)  CSI-RS：32 ports per 5 slots  CSI-RS for IM：ZP CSI-RS with 5 slots period; 4 RE/PRB/5 slots  SSB：1 SSB per 20 ms  TRS：2 consecutive slots per 20ms, 1 port, maximal 52 PRBs |

*Note: Other system configuration parameters align with Report ITU-R M.2412.*

Table A-2

Evaluation assumptions for uplink

|  |  |  |
| --- | --- | --- |
| Configuration parameters | Dense Urban  (Configuration A) | Rural  (Configuration C) |
| Multiple access | CP-OFDM | DFT-S-OFDM |
| Duplexing | TDD | FDD/TDD |
| Network synchronization | Synchronized | Synchronized |
| Coding | LDPC | LDPC |
| Numerology | 30kHz | 15 kHz for FDD, 30 kHz for TDD |
| Simulation bandwidth | 20 MHz | 10 MHz for FDD;  20 MHz for TDD |
| TDD Frame structure | DDDSU | DDDSU |
| Transmission scheme | SU-MIMO | SU-MIMO |
| SU dimension | Up to 2 layers | Up to 2 layers |
| Codeword (CW)-to-layer mapping | For 1~4 layers, CW1; For 5 layers or more, two CWs | For 1~4 layers, CW1; For 5 layers or more, two CWs |
| Re-transmission delay | Next available slot | Next available slot |
| Antenna configuration at TRxP | For 32R: (M,N,P,Mg,Ng; Mp,Np)= (8,8,2,1,1; 2,8)  (dH, dV)=(0.5, 0.8)λ; | 8Rx, (8,4,2,1,1; 1,4) |
| Antenna configuration at UE | For 2T: (M,N,P,Mg,Ng; Mp,Np)= (1,1,2,1,1; 1,1); | For 2T: (M,N,P,Mg,Ng; Mp,Np)= (1,1,2,1,1; 1,1) |
| Scheduling | PF | PF |
| Receiver | MMSE-IRC | MMSE-IRC |
| Channel estimation | Non-ideal | Non-ideal |
| Power control parameter | P0=-60, alpha = 0.6 | P0=-76, alpha = 0.8 |
| TRxP number per site | 3 | 3 |
| Mechanic tilt | 90° in GCS | 90° in GCS |
| Electronic tilt | 105° in LCS | 92° in LCS |
| Handover margin (dB) | 1 | 1 |
| Wrapping around method | Geographical distance-based wrapping | Geographical distance-based wrapping |
| Criteria for selection for serving TRxP | RSRP based | RSRP based |
| Overhead | PUCCH: 2 PRB and 14 symbols  DMRS: Type II, one front loaded symbol + 1 addition symbol  SRS：2 symbols per 5 slots | PUCCH: 2 PRB and 14 symbols  DMRS: Type II, one front loaded symbol + 1 addition symbol  SRS：2 symbols per 5 slots |

*Note: Other system configuration parameters align with Report ITU-R M.2412.*

Reference

[1] ITU-R WP 5D: Acknowledgement of candidate RIT submission from TSDSI under Step 3 of the IMT-2020 process. Document IMT-2020/[19(Rev.1)](https://www.itu.int/md/R15-IMT.2020-C-0019/en), 23 December 2019.

[2] 3GPP TS 38.214: "Physical layer procedures for data".

[3] ITU-R: Guidelines for evaluation of radio interface technologies for IMT-2020. Report ITU-R [M.2412-0](https://www.itu.int/pub/R-REP-M.2412-2017), (10/2017).

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1. Submitted on behalf of [Africa Evaluation Group](https://www.itu.int/oth/R0A06000085/en) (AEG). [↑](#footnote-ref-1)