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SPECTRUM ASPECTS & WRC-27 PREPARATIONS

IAFI[1]

PROPOSED UPDATES TO THE WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT ITU-R M.[IMT-TROPO MITIGATION]

Mitigation of interference for IMT network under tropospheric ducting effect

Introduction:

47th WP-5D meeting in October 2024, commenced development of a a working document towards a preliminary draft new ITU-R Report for mitigating interference in IMT systems. This document, annexed as Annexure-5.5 to the 47th WP-5D Chairman's report (C-413), is expected to be further developed in this study cycle. This contribution from IAFI aims to provide additional updates and insights to this on-going effort.

Some operators have reported that remote electromagnetic interference based on tropospheric radio duct phenomenon have occurred on a large scale in their IMT networks and with the continuous expansion of the network scale, the problem will become more and more serious. In general, the TDD network may be more affected by tropospheric radio duct effects, leading to the degradation of network performance indicators. In many cases, the unwanted emission from an aggressor base station antenna can impact with the uplink signals of a victim base station operating tens of kilometers or even hundreds of kilometers away from it.

The troposphere, the lowest layer of Earth's atmosphere where most weather phenomena occur, sometimes exhibits distinct layers of air with varying temperatures and humidity. When a layer of cool, dense air becomes trapped beneath a layer of warmer air, a phenomenon known as a tropospheric duct forms. This duct acts like a waveguide for radio waves, preventing them from dispersing in all directions as they normally would. Instead, the waves become confined within the duct, allowing them to propagate over significantly greater distances than typically expected.

Tropospheric ducting poses a significant challenge for IMT-2020 communications, particularly those employing Time Division Duplexing (TDD). This atmospheric phenomenon allows signals from distant base stations to propagate over abnormally long distances, leading to interference with local 5G signals. TDD systems are especially vulnerable because they utilize the same frequencies for both transmission and reception, increasing their susceptibility to interference from these extraneous signals. This interference can result in reduced network performance, dropped calls, and decreased data speeds.

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[1] ITU-APT Foundation of Inia is a sector member of ITU-R, ITU-T and ITU-D

Proposal:

IAFI though this contribution suggests some further updates in various para of the Working Document [MITIGATION IMT]. Changes proposed are in highlighted in turquoise.

WORKING DOCUMENT TOWARDS A PRELIMINARY DRAFT NEW REPORT
[MITIGATION IMT]

Mitigation of interference for IMT network under tropospheric ducting effect

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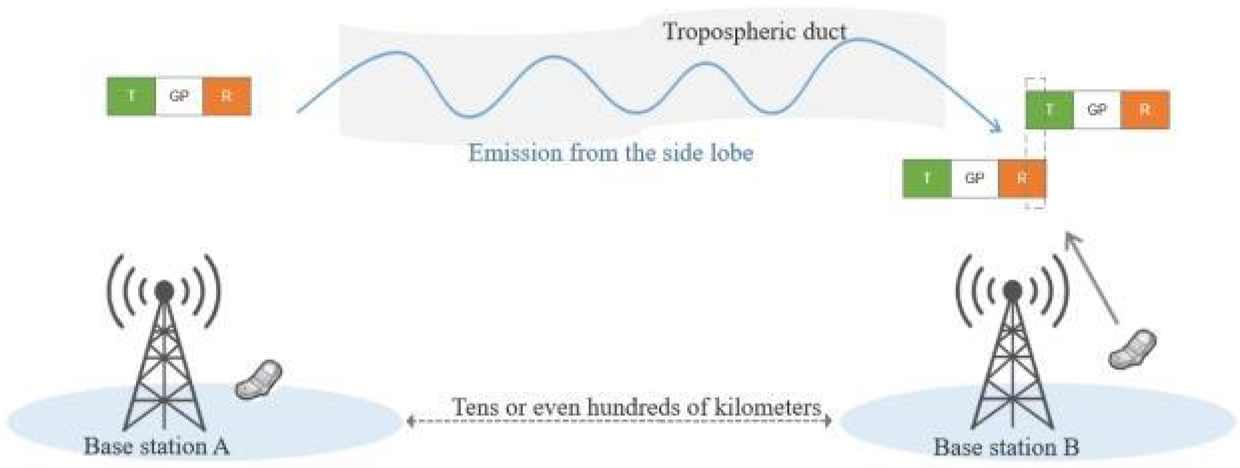
1 Scope

The tropospheric duct phenomenon can cause long-distance propagation of downlink signals, causing interference to IMT (5G) base stations, resulting in severe degradation of network performance. Under certain weather conditions, the tropospheric duct phenomenon happens: the base station signal can propagate in a higher refractive index layer and may experience less attenuation, i.e., in the tropospheric duct, which means the unwanted emissions, which originally also transmit to space, will bend back towards the earth, and cause the propagation delay beyond the guard period. In this case, the unwanted emission from an aggressor base station antenna can impact the uplink signals of a victim base station operating tens of kilometres or even hundreds of kilometres away from it. This Report provides mitigation techniques to reduce interference.

FIGURE 1

The proportion of the propagation delay goes beyond the guard period



In IMT base stations, such kinds of distanced disturbance have occurred, and with the continuous expansion of the network scalability, the problem will become more and more serious. and in border region methods to mitigate such issues, providing approaches to address unintentional remote and random disturbance from victim's and the aggressor's perspectives.

2 References

The latest version of the Reference should be used

ITU-R Resolution

56 Naming for International Mobile Telecommunications

ITU-R Recommendation

P.452 Prediction procedure for the evaluation of interference between stations on the surface of the Earth at frequencies above about 0.1 GHz.

ITU-R Report

M.2410 Minimum requirements related to technical performance for IMT-2020 radio interface(s).

3GPP TR 38.866 Study on remote interference management for NR.

3 Definitions

3.1 **Distributed nodes:** Each node collects the parameter and real-time interference data of the base stations in the jurisdiction area, forms the inter-area interference path relationship information, and parses out the key interference data and transmits them back to the network centre control node.

3.2 **Guard period (GP):** The guard period is the time interval when the base station switches from the transmitting function to the receiving function. It is mainly used to avoid uplink signal suffering the interference from the downlink signal. When tropospheric duct exists, the duration of GP between base stations

3.3 **Network centre control node:** The data aggregation centre of distributed nodes, with the functions of aggregating and analysing interference data and issuing adjustment instructions.

3.4 **Network performance assurance mechanism:** Through the collaboration between central control nodes and distributed nodes within the network, beneficial measures will be applied to all base stations affected by the tropospheric duct phenomenon to ensure network performance.

3.5 **Reference signal (RS):** The signal, which is transmitted by a victim base station, includes the identification of the base station, is characterized by the transmission frequency, transmission frame number and selected random sequence. When the aggressor received the signal, the identification of the victim base station can be known, and the mutual interference relationship will be established.

3.6 **Timing advance (TA):** The control of the uplink transmission timing of individual User Equipment (UE). It helps to ensure that uplink transmissions from all UE are synchronized when received by the base station. See https://www.nrexplained.com/ta.

3.7 **Top aggressors:** The base stations that cause the most victim base stations and cause the most serious interference when tropospheric duct exists.

3.8 **QRxLevMin:** The minimum access level of the cell, in dBm.

4 Abbreviations and acronyms

CIO	Cell Individual Offset
FDD	Frequency Division Duplex
GP	Guard Period
KPI	Key Performance Indicator
OFDM	Orthogonal Frequency Division Multiplexing
gNB	Next generation node B
NR	New Radio
RRC	Radio Resource Control
RS	Reference Signal
TA	Timing Advance
TDD	Time Division Duplex
UE	User Equipment

RIM Remote Interference Management5 Overview of measures to ensure IMT (5G) network performance

To address the interference issues with 5G base stations caused by tropospheric duct effects, currently with Reference Signal (RS) sequences, IMT base station can locate the tropospheric duct interference and adjust automatically.

In practical applications, the remote interference management function of IMT devices can control the influence of tropospheric duct interference to a certain extent, but it still needs to be further optimized and adjusted by engineering optimization. To further address t interference with 5G base stations caused by these effects, a coordinated optimization mechanism between aggressor and victim base stations is developed to mitigate the impact of such unintentional interference on the network.

One mitigation way is the collaborative optimization of aggressor base stations. The RS sequence detection results, which are extracted by 5G base stations in each area, will be aggregated and analysed. According to the localization threshold, the aggressors which are most interfering will be selected, for example, base stations with wide coverage and strong impact. Optimization can be carried out for such aggressors' base stations, by increasing the protection distance and guard period[2], reducing power and unwanted emissions, increasing tilt angle, reducing the elevation sidelobes of the antennas, inadvertently entering via the duct. 3GPP TR 38.866 V16.1.0 section 6.4.1.3 "Spatial-domain based solutions" provides significant information.

Another way is the automatic avoidance of the susceptible victim. Through coordinated optimization of and FDD networks, the affected network users are migrated to FDD networks, that are unaffected by the effects.

A comprehensive performance assurance mechanism can find the balance between aggressors and victims, achieving the best optimization results with minimal resource loss. It can effectively prevent the problem where base stations immediately become aggressors again, after optimization adjustments, before the tropospheric duct effects subside.

6 Measurement and optimization of aggressors

To reduce interference from 5G base stations caused by tropospheric duct effects, in the aggressor side, to reduce impact by using some means, for example, aggressor measurement, the selection method of aggressor-optimization implementation, etc.

6.1 RIM data analysis

According to RIM of 5G, a RS sequence, which including the gNB information of a 5G base station, can be sent when the base station is suspected of being impacted by the interference under tropospheric duct effects. According to the reciprocity of the channel, the aggressor base station can decode the gNB information of the base station after receiving the RS sequence, so as to realize pathway location.

The RS sequence detection result can be extracted from the base station, mainly including the detection base station identification, cell identification, interference source identification, interference power and other information, as shown in the following table:

[2] The current guard period of 5G base station is 42 km.

TABLE 1

RS sequence detection result

Name	Sample Data
Year	2021
Month	6
Day	6
Hour	23
Minute	51
gNodeB ID (Victim)	10,500,353
CellID	1
Power	–108 dBm/360 kHz
gNodeB ID (Aggressor)	160,405

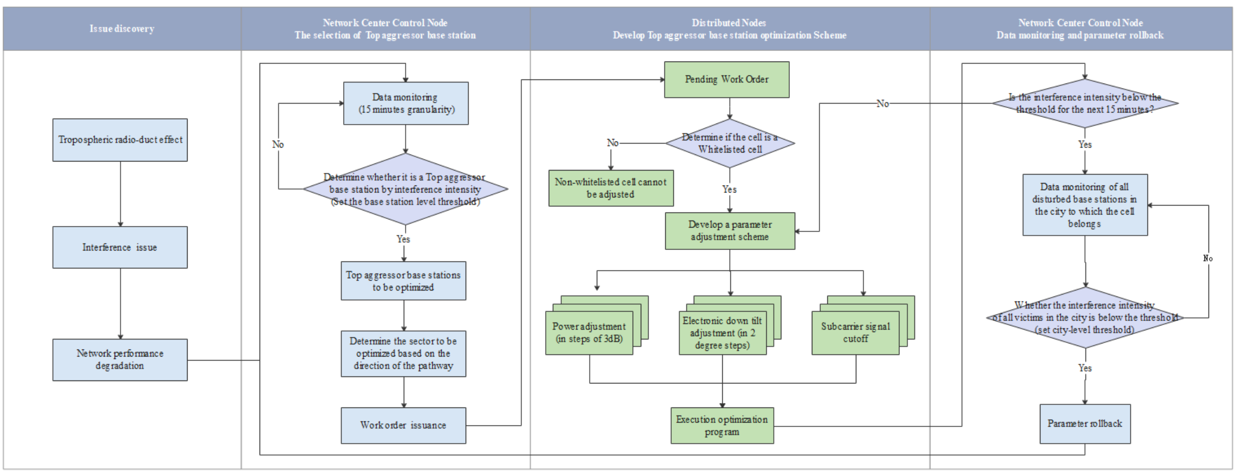
6.2 The optimization of Top aggressor

Specific network performance assurance mechanism can be used for the selected base stations which are most needed to be optimized, including the increase of the GP, reducing the transmit power and adjusting the antenna tilt.

Currently, in most cases, each region is independently optimizing its own 5G networks. However, there are cross-regional interference caused by tropospheric duct effects, where a base station in one range can influence a station in another range. To address this problem, it is important to implement an automatic optimization scheme that encourages cooperation among aggressors, to ensure the network performance. The diagram below illustrates this process.

FIGURE 2

Tropospheric duct interference aggressor base station collaborative optimization and performance assurance measures flow chart



1) Selection of Top aggressor base stations

Based on the key interference data fed back from the distributed nodes, the network centre control node aggregates and calculates according to the interference-level, the frequency and power to select the aggressors, i.e., which frequently and severely interfere others.

2) Setup and maintenance of whitelist for cell

Cells that can be optimized through parameter adjustment are added to a whitelist. The current transmission power and tilt angle ranges for each base station are determined by updating whitelist information. Only cells on the whitelist can undergo parameter optimization adjustments.

3) Optimization plan creation & implementation

If a Top Aggressor is on the whitelist, the current parameter settings and adjustable ranges are obtained. Its power value and tilt angle are adjusted by using a set step, or turn off some downlink symbols.

4) Parameter monitoring

It is a crucial step in resolving interference caused by Top Aggressors. Once the transmission power and tilt angle of the aggressors have been adjusted, each step is carefully monitored. If the interference persists, the parameters are modified and tested again until a resolution is found.

This real-time monitoring process not only resolves the interference but also determines whether the parameter rollback process should be initiated, to avoid repetitive adjustments. By closely monitoring the parameters and their effects, troubleshoot can be swiftly and effectively solved, leading to optimal performance and results.

5) Parameter rollback

When the influence of the monitored effect dissipates or is mitigated, the parameters of the affected individuals revert back to their original state.

6.2.1 The selection of Top aggressor

From collaborative optimization of aggressor perspective, through a performance assurance mechanism, the detection results of RS sequences and engineering parameter data from 5G base stations in various regions are aggregated and analysed. According to the localization threshold, the aggressors which are most needed to be optimized will be selected, then carry out the optimization work.

6.2.2 Increase GP of Top aggressors

When the special subframe configuration of the 5G TOP aggressor site is 6:4:4, the length of the GP is 4 OFDM symbols, and the guard distance is about 42.84 km.Increase the GP (Each additional symbol of the GP can extend the protection distance by about 10.71 km) can effectively avoid the interference to base stations which in the protection distance extension area.

6.2.3 Reduce transmit power of Top aggressors

To mitigate the impact of aggressor base stations on the electromagnetic compatibility characteristics of other base stations, their transmission power may be reduced, through performance assurance mechanisms, thereby reducing the unwanted emission power entering the tropospheric radio-duct.

6.2.4 Adjustment of the Top Aggressors' antenna

At present, all base stations 5G antennas can be controlled by the network. To minimize tropospheric duct interference from top aggressors, the tilt angle of their antennas can be adjusted through performance assurance measures, to reduce the power of unwanted emission propagated through the duct. It can be also considered replacing an antenna with better sidelobes (in elevation and azimuth) attenuation and third-order intermodulation performance indicators.

6.2.5 Turn off some downlink transmit symbols of Top aggressors

When the interference under tropospheric ducting effects occurs, according to the distance and direction of the interference path, the downlink symbols of the Top aggressor to be shut down is determined by the performance assurance mechanism, and the adjustment instructions are issued by the network center control node and executed by the distributed nodes, thus expanding the protection distance, avoiding or mitigating mutual influences.

6.2.6 Performance Evaluation indicators for optimization effectiveness

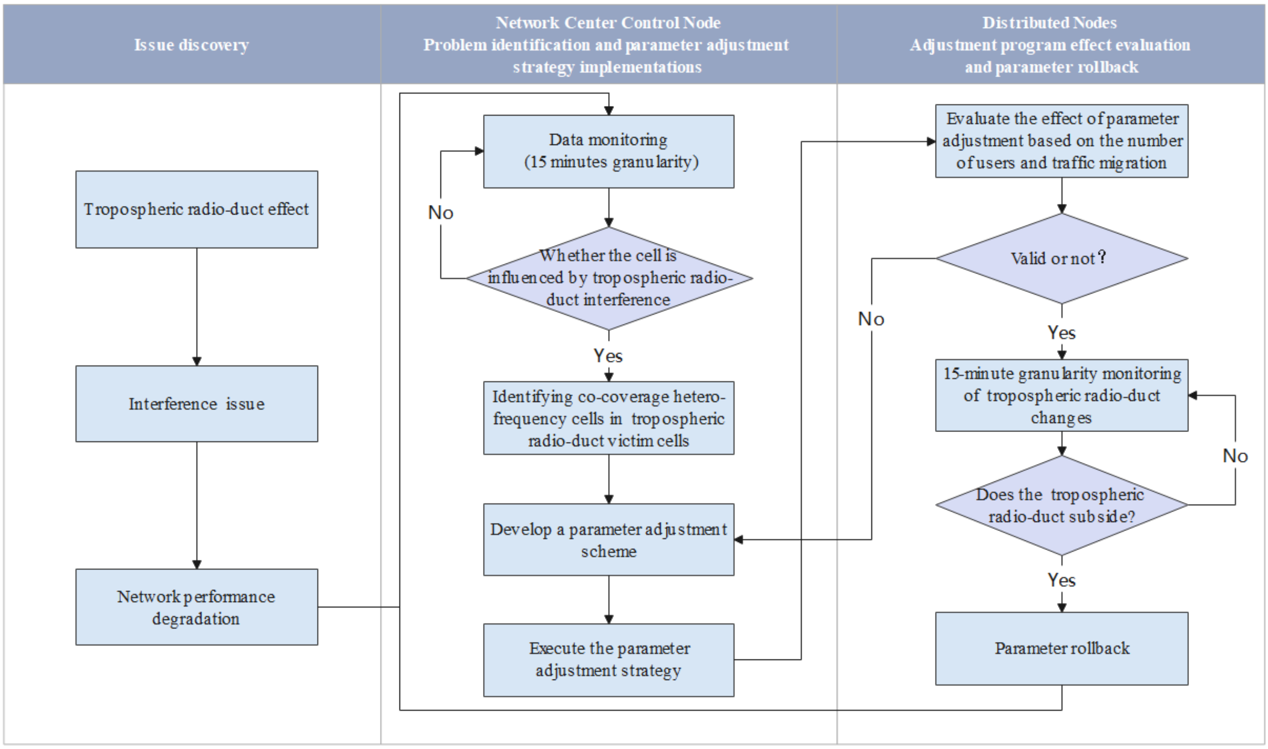
After implementing the above optimization methods, the objectives should include reducing the proportion of interfering cells, improving wireless connection rate, reducing wireless drop rate, and increasing performance metrics such as New Radio (NR) handover success rate.

7 Measurement and Optimization of victim

From the perspective of the victim base station, tropospheric duct interference can be avoided by means of tropospheric duct interference identification, uplink anti-interference ability enhancement, and user migration from multi-layer networks to reduce the impact on users' perception.

FIGURE 3

Tropospheric duct interference in victim cells optimization flow chart



7.1 Identification of victim

With RS detection data, it is possible to judge whether the cell is influenced by tropospheric duct, ensure the victim cells, and then through the performance assurance mechanism to implement targeted interference avoidance and user migration.

To identify victim cells affected by the tropospheric duct effect, the successful reception is tracked of RS and measuring the interference power of a base station during a specified time period.

7.2 Ensure the performance of uplink

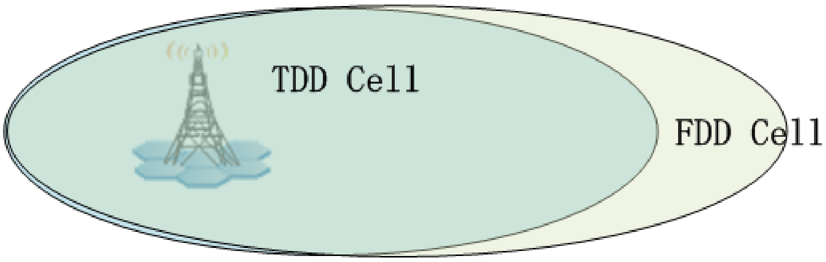
When the main Key Performance Indicator (KPI) such as cell call completing rate, dropped call rate, and switching success rate are impacted by the tropospheric duct effect, the affected cell is designated as a victim requiring migration.

7.3 User migration between multi-frequency networks

Due to the use of different frequencies for the uplink and downlink, FDD cells do less experience interreference to wireless base stations caused by tropospheric duct effects. Therefore, in the event of this interference, users can be migrated to FDD cells using the same coverage cell data table, and information about all co-frequency cells of the victim cell can be obtained. Based on this information, parameter strategies can be developed to mitigate the interference, including reducing the transmission power of cells, increasing QRxLevMin of cells, and increasing the CIO between cells and co-coverage FDD cells. This strategy allows the migration of edge users of the victim cell and reduces the impact of the problem on user perception.

FIGURE 4

Schematic diagram of different frequency cells with the same coverage



7.4 Performance Evaluation Indicators for Optimization Effectiveness

After implementing the above optimization methods, improvements should be achieved in performance indicators such as wireless connection rate, wireless drop rate, and NR handover success rate.

8 Future prospects

The current interference avoidance strategy is formulated after the occurrence of tropospheric duct effects, with adjustments made through performance assurance mechanisms. In the future, artificial intelligence and big data may reduce tropospheric duct effects, may provide prediction algorithms. Interference avoidance measures can be issued in advance to further reduce the impact of interference.

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