Novel Test Methods for 5G Network Performance Field Trial

Xin Li[1], Wei Deng[1], Lei Liu[1], Yuqi Tian[1], Hui Tong[1], Jianhua Liu[1], Yi Ma[2], Jiangzhou Wang[3], Seppo Horsmanheimo[4], Anastasius Gavras[5]
[1]China Mobile Research Institute, Beijing, China; [2]University of Surrey, Surrey, GU2 7XH, UK; [3]University of Kent, Canterbury, CT2 7NZ, UK; [4]VTT Technical Research Centre of Finland, Espoo, Finland; [5]EURESCOM, Heidelberg, Germany

***Abstract*—In this paper, several novel test methods are proposed for 5G mobile network field trials. As it is known, field trial plays an important role in wireless network commercialization process. However, several new technologies have been considered in 5G communication networks, such as massive MIMO. Therefore, conventional filed trial methods used in 4G mobile networks cannot fulfill the new test requirements for 5G mobile networks. Four new field trial methods have been discussed in our work. Moreover, real measurement data has been collected to demonstrate the proposed methods from 5G large scale filed trial supported by China Mobile Communications Group Co., Ltd.**

Keywords—5G field trial, interference measurement, drive test, MU-MIMO, down-tilt.

I. INTRODUCTION

In the process of 5G mobile network development from standardization to commercialization, field trial is an essential step. The field trial is performed in a real network environment, which can objectively evaluate the network performance. Meanwhile, it can help to identify business and technical problems, effectively promote the maturity of the business, and accumulate valuable experience for the subsequent commercial network scale, networking, construction, and operation and maintenance. Comparing with 4G mobile networks, a few advanced technologies have been introduced into 5G [1-2], such as massive MIMO [3-4]. Therefore, the methods used for 4G field trial cannot fully and accurately evaluate the performance of 5G technology. New test methods designed for 5G field trial are in great need.

II. INTERFERENCE SCRAMBLING METHODS

During the network field trial, in order to simulate the real network environment performance, a certain degree of interference needs to be applied in the test environment. The scrambling method used in the test should fulfil the following two requirements.

1) Reality: the method of generating interference should be consistent with the method of generating interference in the real network as much as possible.

2) Controllable: simple methods should be able to use to precisely control the degree of interference to facilitate the development of testing.

The scrambling methods used in 5G network field trial should meet the above two requirements. The basic idea is to employ the orthogonal channel noise generation (OCNG) scrambling method in the 4G mobile network trial and increase the beam scanning with characteristics of the 5G mobile network.

OCNG has been widely used in 4G network filed trial. In 4G network, interference is mainly caused by user usage. When the base station performs scheduling for users in the cell, certain frequency resources are allocated to use in the cell. Due to the orthogonality between the frequency resource in the cell [5, 6], there will be no interference between users in the cell as the load of the cell increases. However, for the neighbouring cells, these occupied frequency resources will cause interference. The OCNG scheme can realistically simulate this process. When there are no real users in the test cell, the scrambling module can generate some occupied frequency resources served as “real” users. These occupied frequency resources are then transmitted through the wireless channels. This scheme also has good controllability as the degree of OCNG interference can be controlled by the proportion of frequency resources. For example, if the system has a total of 100 physical resource blocks (PRBs) in one transmission time interval (TTI), when 50 PRBs are occupied by analogue scrambling.

The 5G physical layer technology employs multi-antenna beamforming while continuing to employ the OFDM and conventional MIMO technology [5, 6]. Therefore, in addition to frequency resource occupation, the interference scrambling scheme of 5G field trial should also consider the characteristics of beamforming. This is because although the interference can occupy the same time-frequency resources, if the beam directions are different, the interference level to the measured object will change along with it. To meet this new challenge, a novel interference scrambling method has been proposed for 5G field trial through considering both “OCNG and beam scanning”.

A. Beam Scanning Requirements

There are three requirements to perform the beam scanning,

- The PDSCH scrambled beam is divided into several vertical layers, e.g., divided into 3 layers as shown in Figure 1-a, each vertical layer is divided into several horizontal directions, e.g., divided into 8 directions as shown in Figure 1-b. Therefore, in total there are 24 subdivision scrambling directions.
- In each TTI scheduling cycle, one direction is selected from these 24 subdivision scrambling directions, and PDSCH OCNG scrambling is performed in this direction. Considering the randomness of the beamforming direction in the real network, the direction during scrambling should be randomly selected, or from the 24 subdivision scrambling directions in order.
- The PDSCH simulation scrambled beam width should be consistent with the actual 15 ° horizontal and 6 ° vertical.

B. OCNG Scrambling Requirements

Since the OCNG scrambling scheme was proposed, after continuous application and improvement of 4G and 5G

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large-scale tests, the functions have gradually stabilized. The specific requirements are listed as below.

- Loading: on each TTI, the RB occupied by random data generated by OCNG/all RB resources of PDSCH of this TTI
- Random change period: the interference RB generated by OCNG should be changed randomly again after maintaining a maximum of n slots. In practice, n is usually set to 10.
- The test cell should not be affected. In the cell where the test terminal resides, the OCNG function of the cell still exists, but it does not interference with the test terminal (do not interference with the test terminal on the same RB).
- Maintaining interference level: if in one time slot, the test terminal only occupies a small part of PDSCH RB, which the load cannot meet the requirement of the interference configuration. The OCNG should be able to fill up the remaining interference.
- Stopping condition: if the test terminal has occupied the more resource in one slot than OCNG interference load, then OCNG will stop work to add any extra interference.

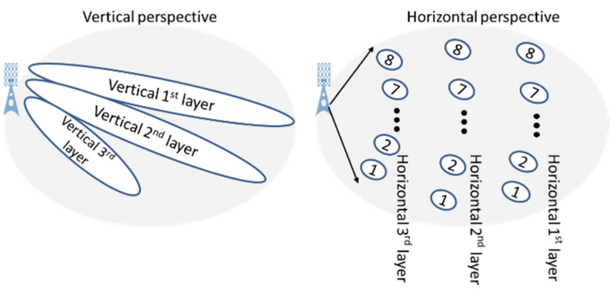

Figure 1. Beam Scanning Requirement.

C. Results Evaluation

- Test 1: Comparison of SNR/SINR for isolated base station, interference with no scrambling and interference with scrambling. In the isolated base station test, only the base station in the test cell is turned on, so the SSB SINR is in the cell is high. In the test with interference but no scrambling test, the neighbouring cell also broadcasts so it interferes the SSB of the test cell. In the test with interference and scrambling, the interference level to SSB is kept the same, the scrambling is only performed to PDSCH channel only as described above.

Figure 2. SINR comparation among three cases: isolated base station, interference without scrambling and interference with scrambling.

- Test 2: Downlink data rate for isolated station, interference without scrambling and interference with scrambling. In the case of isolated station and the case with neighbouring cell interference but without scrambling, the obtained down link data rate for both cases are converged after the NR_SS_RSRP value larger than -90 dBm. This is because the PDSCH channel in not interfered. In the case with interference and scrambling to the PDSCH channel, the downlink data rate is lower than the first two cases due to the interference added to PDSCH channel.

Figure 3. PDCP comparation among three cases: isolated base station, interference without scrambling and interference with scrambling.

III. The Maximum Single UE Distance from the AP

Here, the maximum single UE distance from the AP is referred to moving a UE that is doing uplink or down link services from the center of the cell and continuously moving away from the center of the test cell until it is disconnected. The motivations of this test are,

- obtain the ultimate coverage capability (in terms of distance or minimum level) of the technology being evaluated;
- it can help to analyze the restricted channel of the technology being evaluated, so that it can be improved in the future
- it can help to understand the general relationship between signal strength and user experience data rate for network planning optimization

Different degrees of interference can be applied when conducting the test. Common interference test could include isolated station, interference received from neighboring cell but without scrambling, and interference received from neighboring cell with scrambling. When away from the center of the test cell, UE can take the direction of the Normal of the test cell, or the direction of an angle of 60 °, as shown in the Figure 4. The difference is that the antenna gain will reach its maximum value in the direction of the Normal. Therefore, the coverage capacity in both directions can be evaluated.

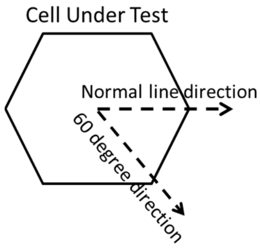

Figure 4. Two ways to move UE away from the center of the test cell.

A. Test Methods

The test terminal is placed in the test vehicle with GPS turned on, and the downlink full buffer TCP services is initialized. The test vehicle drive from a good point of the test cell to the edge of the cell with moderate speed until the connection between UE and AP dropped. The overall test should be kept at least 10 minutes and 5 minutes in edge.

B. Some test requirements

- GPS: simultaneously, the GPS position of the UE should be recorded during the test to facilitate the calculation of the coverage distance.
- TCP: try to initialize TCP services instead of UDP. The difference between the two is that TCP services have an acknowledgement, but UDP do not require acknowledgement. So UDP could easily achieve higher throughput. However, since real commercial users use TCP services more often, therefore using TCP services for test is closer to the actual user experience.
- Test time: during the test you should move as slowly as possible towards the edge of the cell. Due to the variability of the wireless environment, the signal strength and data rate are constantly changing. Comprehensive measurement results are needed.

C. Results Evaluation

- In isolated station, the minimum user traffic RSRP drops point of about -125 to -128 dBm, the main channel is a restricted channel PUSCH. In the test that interference is received from neighboring cell but no scrambling, the user traffic dropped around -10dB, which is mainly limited by the SSB downlink interference.
- It is observed that the rate of the downlink varies according to the distance and interference.

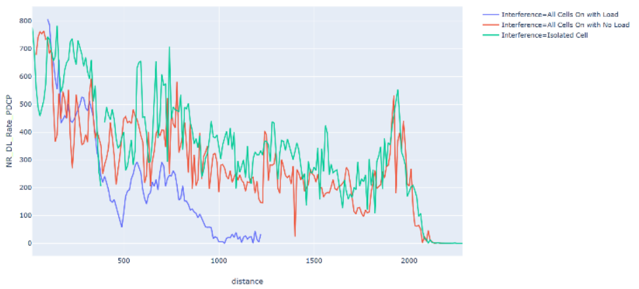

Figure 5. PDCP comparation between interference with and without scrambling.

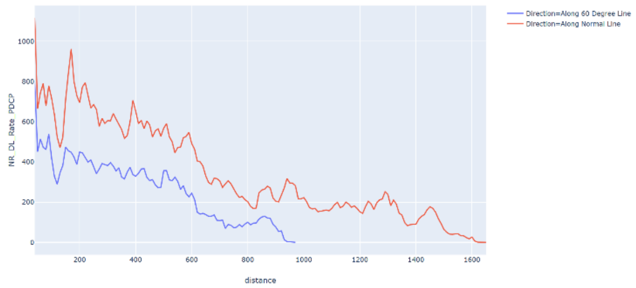

Figure 6. RSRP comparation between interference with and without scrambling.

IV. MU-MIMO TEST

Cell throughput reflects the processing power of the network in a multi-user scenario [7]. Comparing with 4G, 5G's MU-MIMO is enhanced in several aspects:

- New array form: vertical beam dynamic scanning range is 24 degree
- New access method: increasing broadcast narrow beam scanning (the narrowest beam is 15 degree horizontally/6 degree vertically), thereby enhancing public/control channel coverage
- New transmission mode: the maximum number of multi-user orthogonal ports is 12 depending on the DMRS configuration decision, which can reduce the MU-MIMO requirements for spatial isolation to a certain degree. User pairing above 12 streams will rely on air separation.

5G MU-MIMO cell throughput performance is mainly affected by factors such as user distribution mode, services type, user movement speed and neighbouring cell interference. When multiple users are located at similar channel quality positions, it is easy to pair. However, if multiple users are at the locations with various quality, i.e., good point, medium point and poor point, it is difficulty to be paired. At the same time, there is sufficient space or beam isolation between multiple users, making pairing easier. Full buffer services will be easier to pair than burst services. When the user moves quickly, the DMRS channel estimation is not accurate, which will affect the pairing. Moreover, the neighbouring cell interference situation of the cell will also affect the cell throughput level.

Since the user pairing is very sensitive to the interference, to have more precious test results, each user should be independently chosen from different beams as much as possible. A certain spatial distance should be maintained among different users when the test location points are chosen. As shown in the Figure 7, within the coverage of the base station, circle with r_1, r_2 and r_3 radiuses respectively represent different vertical plane beam coverage. The circular areas between each two rays from the centre of circle represent different horizontal plane beam coverage. In order to have the maximum pairing between users, the minimum distance between two users P_1 and P_2 should be d.

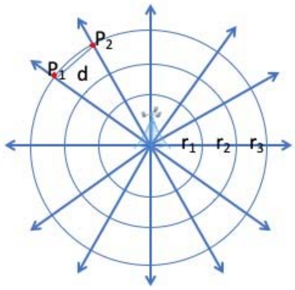

Figure 7. User scheduling for MU-MIMO.

A. *Test Methods*

- Test peak cell throughput: select multiple excellent points in the cell, place multiple test terminals on the selected excellent points, and initialize the full buffer service. Note that excellent points should be spaced apart and evenly spaced.
- Test cell average throughput:
    - Static scenario: users are evenly distributed. In this case, a relatively ideal average cell throughput will be obtained. Select the uniformly distributed excellent points, good points, midpoints, and poor points in the cell in a ratio of 1:2:4:3, place multiple test terminals on the selected points, and initiate the full buffer or burst service to compare the performance differences between the two services.

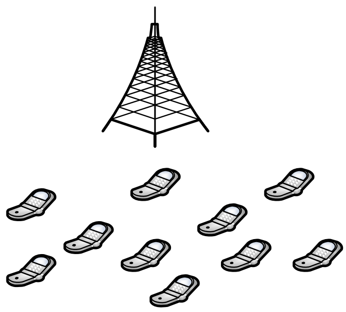

Figure 8. Static scenario setup.

- Moving scenario: the cell throughput obtained at this time is closer to the actual situation. Selected uniformly distributed excellent point, good point, medium point and poor point (including indoor scenario) for testing. A test terminal is moving near each point at 3km/h .Four test terminals are moving from good point to poor point at the speed of 3km/h and two test terminals are moving from good point to poor point at the speed of 30km/h.

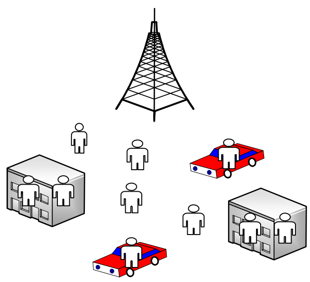

Figure 9. Moving scenario setup.

- Vehicle scenario: in this case, due to the inaccurate DMRS channel estimation, it is not easy for users to pair with each other, and the worst cell throughput performance is obtained through testing. Ten test terminals are placed in two or three vehicles, and tests are exhaustively done with the test area.

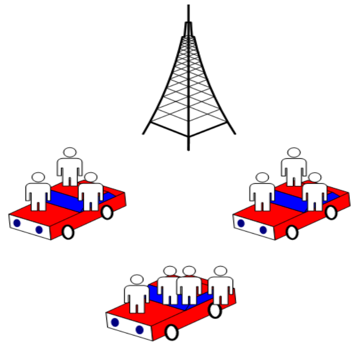

Figure 10. Vehicle scenario setup.

B. *Results Analysis*

Using the above test method, it is found that the peak throughput of the cell can reach 4.6-5.1Gbps downlink and 610-650 Mbps uplink. The average cell throughput (static scenario) compared with the peak value, the user signal strength and isolation become worse. The downlink is 3.8 to 3.9 Gbps, the uplink is 510 to 520 Mbps, and the performance is two to four times that of the burst service. The average cell throghput (mobile scenario) is 600 Mbps to 1.1 Gbps, and the average cell throughput (vehicle scenario) is 500 to 800 Mbps. The channel environment between different users varies greatly, the accuracy of channel estimation decreases, and the performance of multi-user scheduling decreases 45% to 75% lower than static scenario.

V. VERTICAL DIMENSION TEST

One of the major technical features of the 5G system is the large-scale antenna technology, that is, the number of digital processing channels of the antenna has been greatly increased, from 8 channels for 4G to 32 channels or even 64 channels for 5G. By increasing the number of channels, the base station can directly beam the terminal much better, therefore, improving coverage and cell capacity.

The typical configuration of large-scale antenna base stations currently deployed in 5G is a 192-element, 32- or 64-channel antenna array, as shown in the Figure 11 below. Among them, the antenna elements are arranged 8 horizontal and 12 vertically. After considering dual polarization, there are 192 elements in total. For a 64-channel device, a one-to-three structure is used, that is, three oscillators in the vertical dimension are mapped onto a digital channel, and the number of channels is 192/3 = 64. For a 32-channel device, a 1-to-6 configuration is adopted, that is, six consecutive vibrators in a vertical dimension are mapped onto a digital channel, and the number of channels is 192/6 = 32.

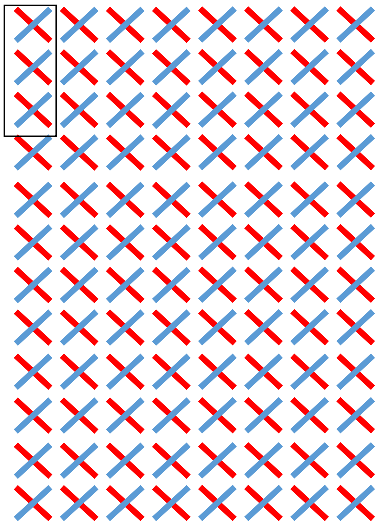

Figure 11. 5G 192 dipoles antenna design.

The design of a conventional 8-channel 4G antenna is as shown as below in Figure 12 [8], with a total of 96 dipoles, 4 horizontal and 12 vertical, plus dual polarization, a total of 96 dipoles. The 8-channel device adopts a 1-to-12 configuration, that is, 12 transducers in the vertical dimension are mapped onto a digital channel, and the number of channels is 96/12 = 8. Therefore, in the vertical dimension, the new antenna array of 5G and the original antenna array of 4G have 12 oscillators. The difference is that 5G has 4 channels (one for three) or 2 channels (one for 6) in the vertical dimension, and 4G has only one channel (one for twelve) in the vertical dimension. Due to the difference of the vertical dimension of the surface in terms of hardware, 4 / 5G antenna pattern in the vertical dimension of the waveform is not the same. A waveform graph 3dB band width of the vertical dimension of the beam 6 is fixed in 4G, as shown in Figure 13.

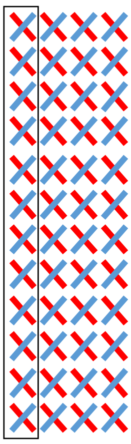

Figure 12. 4G 96 dipoles antenna design.

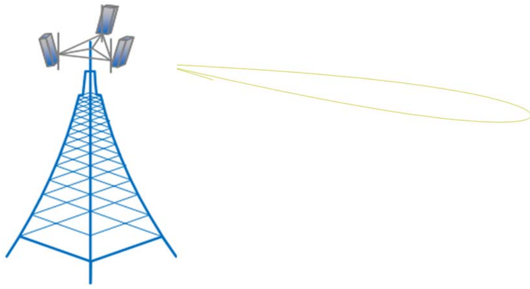

Figure 13. 4G vertical dimension beam.

Compared with 4G, 5G large-scale antenna systems can use wider vertical dimension beams, as shown in the figure below. The vertical-dimensional beam width of the LTE system is about 6 degrees (assuming a FAD antenna), and the vertical-dimensional beam width of the 64-channel large-scale antenna is 24 degrees, which is significantly larger than that of the LTE system.

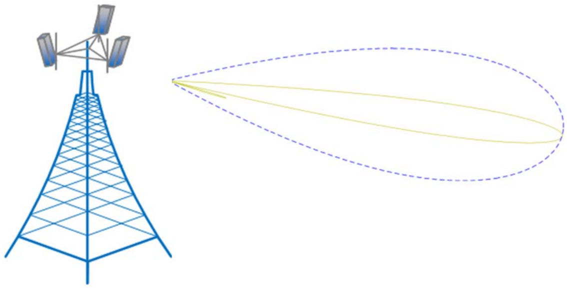

Figure 14. 5G vertical dimension beam.

In this case, if 5G and LTE use the same downtilt, a large-scale antenna has a lot of energy to hit the cell boundary. As shown in the figure below, in the case of the same downtilt, a large-scale antenna has a beam range of 9 degrees beyond the cell boundary, that is, less than half of the energy becomes adjacent cell interference.

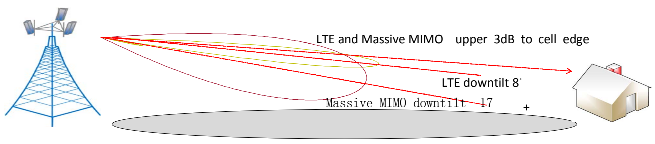

Figure 15. Proposed down-tilt angle method for 5G

In light of the above-mentioned problem of neighboring cell interference, we proposed a method of aligning the upper 3dB point of a large-scale antenna with the cell edge, which is the figure above. In this case, the normal directions of the LTE and 5G antennas are inconsistent, and the direction of the LTE is higher. The down-tilt of the large-scale antenna needs to be increased by about 9 degrees compared to the

LTE down-tilt, which may actually reach 17 degrees. Since the angle of inclination of 17 degrees to realize in a practical system may be difficult, it is also conceivable to make the tilt angle at 14 degrees (e.g. mechanical tilt degree 8 plus preset tilt degree 6 configuration).

A. *Test Methods*

In order to verify the feasibility of the scheme, we conducted corresponding tests during the scale test. The 64-channel device CSI- RS beams are arranged to vertically transmit three , four vertical transmission (each narrow beam 6 °) , while the latter attempts the 3dB beam 2 points to the cell edge , the edge point and the normal vector Two situations. That is, there are three test configurations in the following table :

Table 1 Test configuration

	CSI-RS vertical layers	Beam 2 pointing
Configure 1	3	Point to the edge at 3dB
Configure 2	4	Normal points to the edge(up-scaling)
Configure 3	4	Point to the edge at 3dB,shown in Figure 16 (down-press)

Below, in each configuration, a near building and a far building from the base station are selected. Downlink traffic are initiated on the low, middle and high floor in each building. RSRP, SINR, downlink rate and other indicators are tested and recorded.

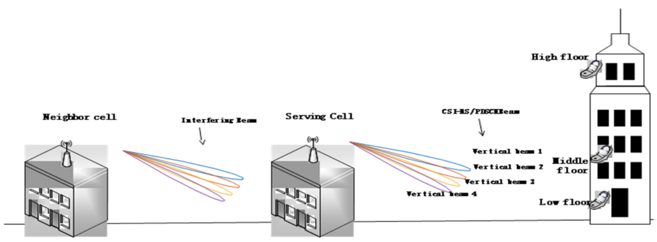

Figure 16. Test method for configure 3

B. *Results Analysis*

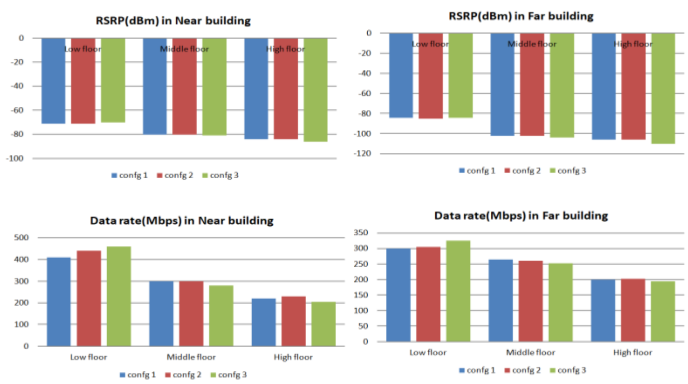

Figure 17. Comparison with different CSI-RS setup

As shown in Figure 17, configuration one is three-beam, configuration two is four-beam up, and configuration three is four-beam pushdown (the correct approach is to push down the adjacent cell-yellow data). It can be seen from the test results that the performance of three-beam and four-beam is similar but slightly lower. The four- beam down-press performance is slightly better on the low floor (relative to the four-beam up-scaling), while the four- beam down-press performance on the high floor is slightly lower (compared to the four-beam up-scaling). In the end, all performance differences are below 10%, so it can be concluded that, due to the reduction of neighboring cell interference, beam depression does not significantly reduce the coverage performance of high floors.

VI. Conclusion

The evolution of each generation of communication technology has brought about the evolution of test methods and test tools. In this article, we have shared some of the 5G wireless network test methods that have been explored during China Mobile's 5G scale trials and strived to truly and accurately evaluate the performance of 5G networks in typical deployment environments.

Acknowledgment

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