Interference Reduction Technique in WCDMA using Cell Resizing

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Abstract - **In WCDMA, the interference is produced by different factors such as thermal noise, intra cell traffic, traffic in adjacent cells and external traffic. In addition, the increase in number of users in a cell consequently increases the total interference in the network. Hence, the interference must be controlled to improve the throughput of the network. In this paper, we propose an Interference Revocation Technique in WCDMA using Cell Resizing approach. Our technique classifies the access points into three types as normal, saturated and cooperative based on its signal to noise ratio (SNR). The saturated cell triggers the process of cell resizing. This process balances the number of users in each cell and thereby cancels the interference completely. We prove the efficiency of our technique through simulation results.**

***Keywords* – Call admission control, Cell Resizing, electromagnetic compatibility, Radio Frequency, Signal to Noise Ratio, Wide Band Code Division Multiple Access**

I. INTRODUCTION

A. Wideband Code Division Multiple Access (W-CDMA)

Wideband Code Division Multiple Access (W-CDMA) is an approved 3G technology which increases data transmission rates via the Code Division Multiplexing air interface rather than the Time Division Multiplexing air interface of GSM systems. It supports very high-speed multimedia services such as full-motion video, Internet access and video conferencing. It can also easily handle bandwidth-intensive applications such as data and image transmission via the Internet. WCDMA is a direct spread technology it spreads its transmissions over a wide range, 5MHz carrier and can carry both voice and data simultaneously.

It features a peak data rate of 384 kbps with peak network downlink speed of 2 Mbps and average user of 220-320 kbps. WCDMA boasts increased capacity over EDGE for high-bandwidth applications and features which include, enhanced security, Quality of service, multimedia support and reduced latency. It works with fiber based wireless access using radio over-fiber (RoF) technology. Access schemes effectively combine the high capacity of optical fiber with the flexibility of wireless networks. W-CDMA RoF system will have an impact not only on multiple-user
interference but also on inter-modulation distortion and clipping noise power.

W-CDMA or family of Universal Mobile Telecommunications System (UMTS) along with UMTS-FDD, UTRA-FDD or IMT-2000 CDMA Direct Spread are air interface standard found in 3G mobile telecommunications networks that is being developed as W-CDMA. Unlike GSM and GPRS which rely on the use of the TDMA protocol, WCDMA which is like CDMA allows all users to transmit at the same time and to share the same RF carrier. Each mobile user’s call is uniquely differentiated from other calls by a set of specialized codes added to the transmission. [1]

B. Causes of Interference

With CDMA technology, interference is a critical factor because communications occur on the same frequency band and time slot such as in the UMTS FDD mode. On the one hand, it is directly linked to coverage and capacity of such a network. So, understanding the relationship between coverage and capacity and how it is affected by interference and transmit power is essential for UMTS network planning. The interference level is directly related to the users density in the considered cell and its neighbors and affects both the cell range and the capacity of the system. The higher the number of users in the system, the higher the interference and the smaller the cell range [4].

The causes of interference are diverse. Radio Frequency (RF) interference to mobile communication network may be caused by such parameters as an original dedicated radio system occupying an existing frequency resource, improper network configuration by different operators (value of power), cell overlapping, the radio channel, electromagnetic compatibility(EMC), external interference sources. The primary forms of interference to mobile communication systems mainly include: common-frequency interference, adjacent-frequency interference, out of band spurious emission, inter-modulation emission, and blocking interference. The problem of interference between systems working in different frequencies is caused by hardware problem in the transmitter (Tx) and the receiver (Rx). Also the interference between the Tx and the Rx depends on some parameters such as the interval between the working frequency ranges of the two systems and the spatial distance which separate the Tx and Rx. For a WCDMA system, the interference can be generated by different source, namely, thermal noise, traffic intra-cell, traffic in adjacent cells and external traffic [3].

C. Problem Identification

Call admission control (CAC) is one of the resource management functions, which regulates network access to ensure QoS provisioning. Efficient CAC is necessary for the QoS provisioning in WCDMA environment. In our previous work, we have proposed to design a new fuzzy based CAC with power control for multiple services like voice, video and data for multiclass users. It determines the optimum set of admissible users with optimum transmitting power level using fuzzy logic, to minimize the interference level and call rejection rate.

To cancel the interference completely in WCDMA, in this paper we propose an Interference Revocation Technique in WCDMA using Cell Resizing.

II. RELATED WORKS

Jraifi Abdelouahed [3] has proposed the system in which, radio frequency interference is caused by occupying exiting radio frequency resource, improper configuration of network by different operators, cell overlapping external interference sources and electromagnetic compatibility. Mobile communication interference is common-frequency, adjacent- frequency, out of band spurious emission, inter-modulation emission and blocking interference. He has developed an analytical expression of the Signal to Noise Ratio (SNR) which is used to predict some parameters. By fixing the SNR to a specific value, he has extracted easily information on the optimal numbers of users.

Anis Masmoudi and Sami Tabbane [4] have proposed two systems called uniform and non-uniform traffic environment in interference of WCDMA. It presents an analytical work which provides exact derivations of the general F-factor, CDF and PDF distributions laws, mathematical expressions in WCDMA systems with one interferer. Their approach doesn’t depend on any assumption or values range. They have also investigated the unequally-loaded cell case referring to the more general non-uniform mobile distribution. They have proved that this model refines the planning process and thus increase the quality and capacity of a cellular network

Derong Liu and Hossein Zare [6] have proposed the method to cancel the multi-path interference in WCDMA. The first chips at the beginning of each frame are free from multipath interference. These chip samples with the knowledge of the channel coefficients to estimate the corresponding interfering chips and then cancel the multipath effect from the second chip samples of the received signal. Similarly, these second chips to cancel the multipath effect from the third samples of the received signal. This procedure can be continued until the end of the frame to cancel the multipath effects from the whole frame. It is possible to cancel all multipath effects and recover the orthogonality property of the received signal. This algorithm is not complex and does not consume much time since each information bit can be detected after the interfering chip cancellation is done in a bit interval. The simplicity of the algorithm with the perfect cancellation of multiple access interference (MAI) comes at the expense of noise enhancement. Although this noise enhancement causes a loss of few dBs in signal to noise ratio (SNR) compared to the single user system, the performance of the receiver simulation results show, is much higher than the RAKE receiver and is free from any error floor.

Maan A. S. Al-Adwany et al. [7] have proposed interference canceller. In WCDMA base station receiver, the BER can be considerably reduced by using the proposed interference canceller. Initially, they have extracted the TDMA interference through the use of a low pass FIR filter. They have constructed a threshold circuit to eliminate the residual WCDMA signal that passes with the extracted TDMA signal. Finally, they have also evaluated the performance of WCDMA uplink system for UMTS mobile communications.

Pon Rattanawichai et al. [8] have proposed the Field Programmable Gate Array known as FPGA. It is a self interference cancellation technique based on an adaptive LMS (Least Mean Square) algorithm. With their technique, the field data measured through a RF repeater is adopted to improve a signal quality using the FPGA Virtex@6 HW module. Their technique also reduces the oscillation of the system due to the feedback interference signal coming from transmit antenna of a WCDMA radio repeater. Their technique offers more flexibility.

III. PROPOSED SOLUTION

A. Overview

In this paper, we propose an Interference Revocation Technique in WCDMA using Cell Resizing. In our technique, each access point (AP) periodically measures SNR value. Based on this value, the AP is categorized into three types as normal, saturated and cooperative. Saturated cells are the cells that exceed avg SNR value. When an AP founded to have SNR grater than avg SNR, it invokes cell-resizing approach. The saturated cell transmits SUPPORT-REQ to all its neighboring cells. On receiving this message, cooperative cells replies with SUPPORT-REP. If the saturated cell receives multiple SUPPORT-REPs, then it selects the one that nearer to it. Upon receiving SUPPORT-REP message, the saturated cell shrinks its size to expel the excessive users. Simultaneously, the cooperative cell enlarges its size and accepts expelled users. Thus, our cell resizing approach cancels the interference by balancing the users in cells.

B. Estimation of Signal to Noise Ratio (SNR)

In WCDMA, the signal to noise ratio can be computed as follows, [3]

$$SNR = \left[\left[\frac{B_e}{P_n}\right]^{-1} + \left[ICI\right] + \left[CCI\right]\right]^{-1} \qquad (1)$$

Whereas, $\left(\frac{B_e}{P_n}\right)$ is the signal to noise ratio that is caused by the Additive White Gaussian Noise, ICI represents intra-cell interference, CCI is the co-channel interference, P_n denote noise power and B_e signifies average bit energy.

The average bit energy (B_e) can be obtain as,

$$B_e = avg\ T_r \cdot B_D \qquad (2)$$

Here, $avg\ T_r$ is the average transmitted power and B_D refer to bit duration.

The intra cell interference (*ICI*) of the cell can be obtained as,

$$ICI = \frac{2}{3G} \sum_{n=1}^{N} \frac{T_n}{T_0} \qquad (3)$$

Where, G is the system processing gain, N denotes the number of users; T_n is the average transmitted power.

C. Interference Revocation Using Cell Resizing

The interference in WCDMA is produced by different attributes such as thermal noise, intra cell traffic, traffic in adjacent cells and external traffic. Therefore, we preferred to use signal to noise ratio (SNR) as a suitable metric to estimate the quality of the cell. The SNR value of each cell is directly related to its interference. The increase of number of users in a cell consequently increases the total interference at the access point (AP). In simple, the high SNR value represents the more number of users in that cell. Consequently, low SNR value of the cell denotes less number of users. The cell structure of WCDMA is picturized in figure-1.

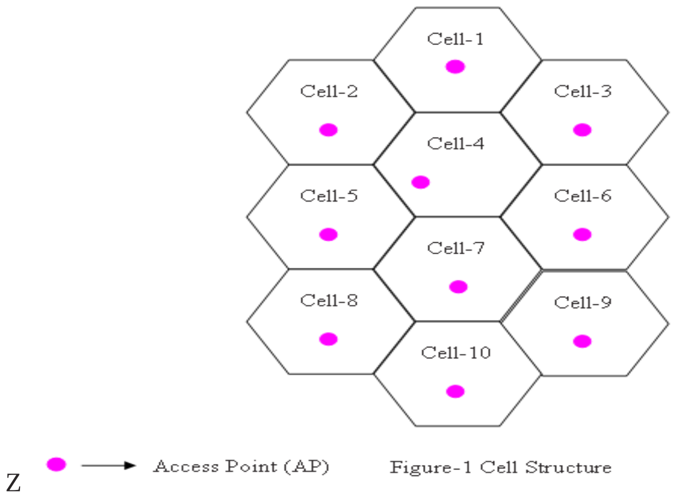

Figure-1 Cell Structure

D. Classification of Access Points

We assume that access point (AP) in every cell is capable of measuring its SNR. The computation method of SNR is described in section 3.2. By considering SNR value of cells, we can categorize them into three states as Normal, Saturated and cooperative.

- **Normal State**

An AP that is in this category will have average SNR value in the neighborhood. The AP's of this type does not require any accomplishment to be done regarding interference.

- **Saturated State**

In this category, the AP's SNR is larger than average SNR in the neighborhood and it is ready to minimize its cell size. This type needs appropriate method to reduce its cell size.

- **Cooperative State**

These AP's have SNR below average SNR in the neighborhood. Converse to the saturated type, this category is ready to increase its cell size.

The classification of access points are portrayed in algorithm-1.

Algorithm-1

Let *avg SNR* be the average signal to noise ratio value
Let *SNR* be the computed SNR value of the cell
(i) If (*SNR = avg SNR)*
 Then
 The AP belongs to Normal State
 End if
(ii) If (*SNR > avg SNR*)

 Then
 The AP belongs to Saturated State
 End if
(iii) If (*SNR < avg SNR*)
 Then
 The AP belongs to Cooperative State
 End if

E. Interference Cancellation using Cell Resizing

After the classification of access points (AP), we can cancel the interference more easily using cell-resizing approach. This approach reduces the size of cell that has more SNR and call off the interference by expelling some nodes to neighbor cell that has low SNR. Cell resizing alleviates the interference of the cell by reducing the number users. That is it achieves interference cancellation by maintaining the number of users in the cell.

The cell resizing approach is performed as follows,

1) When the measured SNR exceeds avg SNR, it is categorized as Saturated and it sends SUPPORT REQ message to all neighboring cells.

$$\text{Saturated Cell} \xrightarrow{SUPPORT-REQ} \text{Neighboring Cells}$$

2) While receiving SUPPORT-REQ, the cells that belong to cooperative state send SUPPORT-REP message to the corresponding cell.

$$\text{Saturated Cell} \xleftarrow{SUPPORT-REP} \text{Cooperative Cell}$$

3) If the Saturated cell receives more than a SUPPORT-REP message, it selects the Cooperative cell that is nearer to it.
4) The Saturated cell shrinks its size to expel some of the users to the Cooperative cell
5) On the other hand, the Cooperative cell enlarge its size to accept new users
6) Both, the Saturated and Cooperative cell estimates the new SNR value.

Consider the cell structure given in figure-1, which consists of 10 cells. In that, consider cell-4 is saturated cell and cell-7 is Cooperative cell. Then the cell resizing approach is portrayed in Figure-2a, 2b and 2c. Figure-2a represents saturated cell and Cooperative cell. As soon as, Cell-4 receives reply from cell-7, it shrinks its size and expels a user. In response to this, Cell-7 enlarges its size and provides accommodations to the expelled user. Now, Saturated and Cooperative cells become Normal cell. Thereby, it cancels the interference.

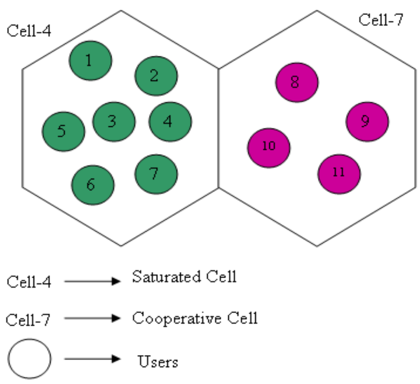

Figure-2a Saturated and Cooperative Cells

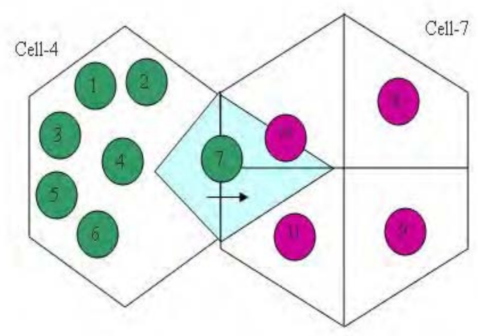

Figure-2b Cell-4 shrinks to expel user 7 to Cell-7

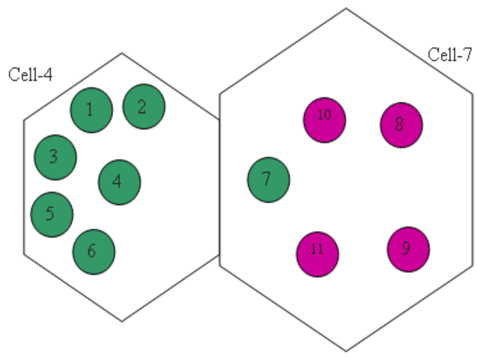

Figure-2c Cell-7 enlarges its size and accepts user-7

The overall process is described in algorithm-2,

Algorithm-2

Step-1

Each AP periodically measures SNR (as per equation-1)

Step-2

AP categorized into three types
(2.1) If (SNR = avg SNR) then it is Normal
(2.2) If (SNR > avg SNR) then it is Saturated
(2.3) If (SNR < avg SNR) then it is Cooperative
Step-3
The Saturated cell transmit SUPPORT-REQ to all its neighboring cells
Step-4
Among neighboring cells, the cooperative cell transmit SUPPORT-REP to the Saturated cell
Step-5
The Saturated cell, reduces its size and expels some users
Step-6
The Cooperative cell enlarges its size and accepts saturated cell
Step-7
The Saturated and Cooperative cell calculates SNR

IV. SIMULATION

A. Simulation Model and Parameters

In this section, we simulate our proposed Interference Reduction Technique using Cell Resizing (IRT-CR) in WCDMA cellular networks. The simulation tool used is NS2 [17], which is a general purpose simulation tool that provides discrete event simulation of user defined networks. In the simulation, mobile nodes move in a 600 meter x 600 meter rectangular region for 50 seconds simulation time. Initial locations and movements of the nodes are obtained using the random waypoint (RWP) model of NS2. All nodes have the same transmission range of 250 meters.
The simulation parameters are summarized in Table 1.

Number Of Nodes	36
No. of Cells	6
Users per Cell	6
Slot Duration	2 msec
SINR threshold	5
Frame Length	3 slots
Txpower	0.66 w
RxPower	0.395 w
Routing Protocol	AODV
Speed of mobile	25 m/s
Traffic Model	CBR
Initial Energy	4.1 J

Table 1- Simulation Parameters

The initial scenario for our experiment is shown in Figure 3. The user 19 from cell 4 and user 25 from cell 6 handoff to cell 5 at 2.00 seconds, there by increasing the load and interference on cell 2, which is illustrated in Figure 4. Similarly, user 40 from cell 2 handoff to cell 3 at 3.00 seconds. Then by our cell resizing concept, user 32 and 33 at cell 5 will be admitted into cell 4 and 6, respectively. Similarly user 12 at cell 3 will be accommodated into cell 2. See Figure 5.

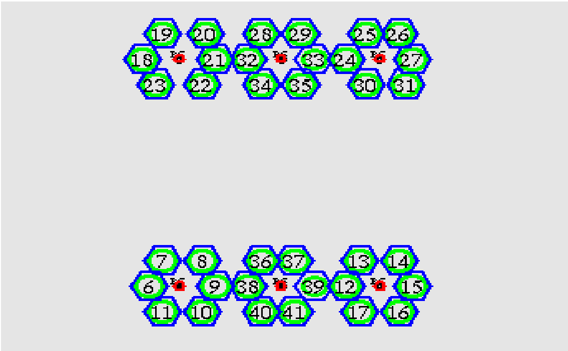

Figure: 3 - Simulation Topology

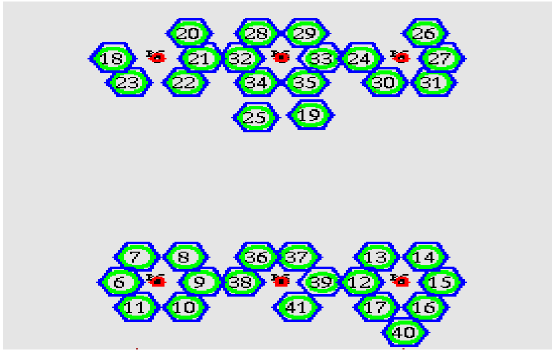

Figure 4 – User Movement

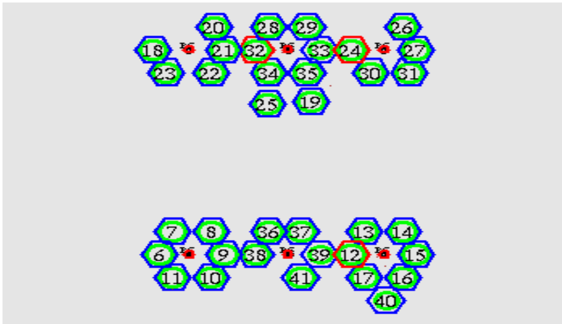

Figure 5 – Cell Resizing based on Users

B. Simulation Results

In our experiment, based on simulation time we measure the average throughput of each cell.

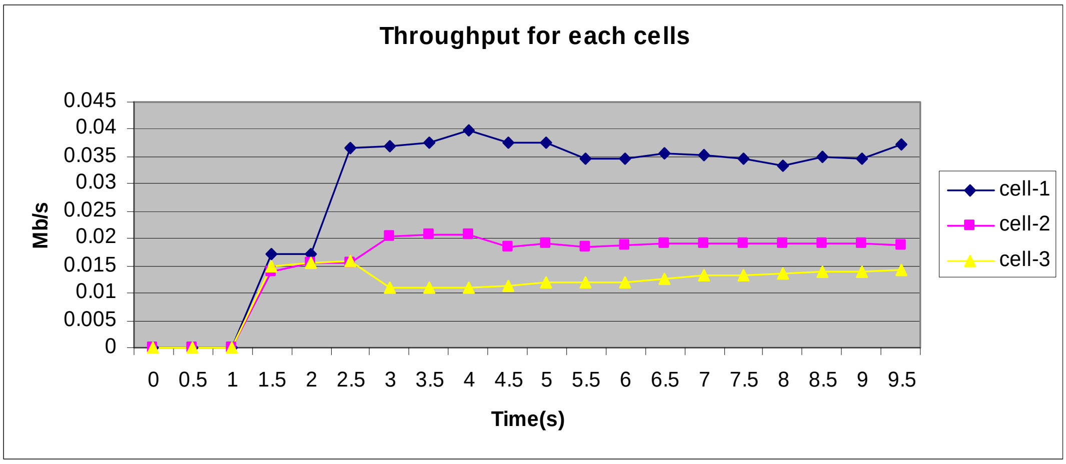

Figure 6. Time Vs Throughput for cells 1-3

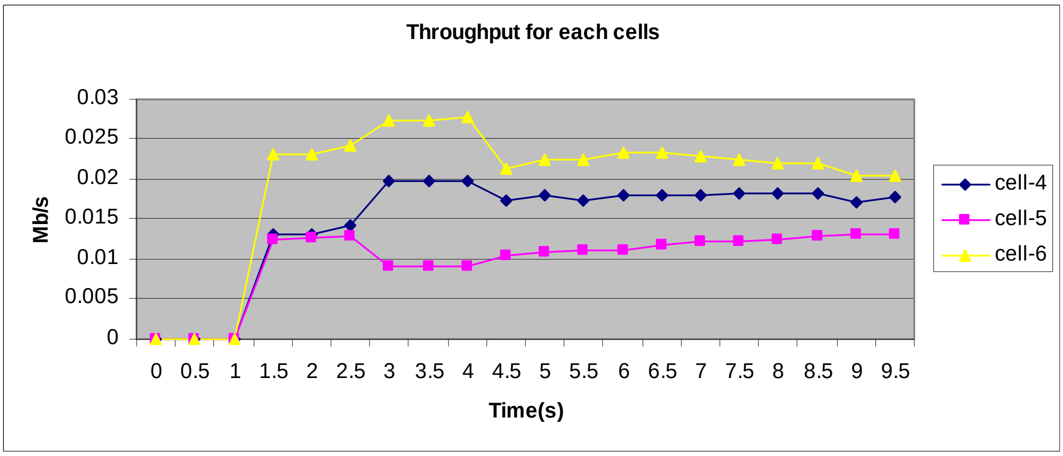

Figure 7. Time Vs Throughput for cells 4-6

Figure 6 shows the average throughput of cells 1 to 3. Since Cell 1 is not affected with any new user's arrival, its throughput is almost constant and high when compared to other cells. Since one user is moved from cell 2 to 3 at 3 seconds, its throughput is increased from 3 to 4.5 seconds. After 4.5 seconds, the cell 2 is resized to accommodate one user from cell 3, so that it decreases and remains constant thereafter. For cell 3, one new user is arrived at 3 seconds. So its throughput falls down from 3 to 4.5 seconds. At 4.5 seconds, the cell 3 is resized to expel one user to cell 2 , there by slightly increasing the throughput.

Figure 7 shows the average throughput of cells 4 to 6. Since one user is moved from cell 4 and 6 to cell 5 at 2.5 seconds, their throughput is increased from 3 to 4.5 seconds. After 4.5 seconds, the cells 4 and 6 are resized to accommodate two users from cell 5, so that the throughput decreases and remains constant thereafter. For cell 5, two new users are arrived at 3 seconds. So its throughput falls down from 3 to 4.5 seconds. At 4.5 seconds, the cell 5 is resized to expel two users to cells 4 and 6, there by slightly increasing the throughput.

V. CONCLUSION

In this paper, we have proposed an Interference Reduction Technique in WCDMA using Cell Resizing technique. In our technique, each access point (AP) periodically measures SNR value. Based on this value, the AP is categorized into three types as normal, saturated and cooperative. Saturated cells are the cells that exceed the avg SNR value. When an AP founded to have SNR grater than avg SNR, it invokes cell-resizing approach. The saturated cell transmits support message to all its neighboring cells. On receiving this message, cooperative cells replies to the corresponding cell. If the saturated cell receives multiple replies, then it selects the one that nearer to it. Upon receiving the reply, the saturated cell shrinks its size to expel the excessive users. Simultaneously, the cooperative cell enlarges its size and accepts expelled users. Thus, our cell resizing approach cancels the interference by balancing the users in cells. We have proved the efficiency of our technique through simulation results. Our technique absolutely cancels the interference. Further, it considerably increases the average throughput of each cells.

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