Fat Time Optimization Protocol In Cellular Networks

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***Abstract*— As the widespread of cellular networks is broadening, the volumes of end-users also keep on increasing exponentially. Amongst the primeval issues, the concern of providing high throughput along with a decent fairness, surfaces with the ever expanding reign of cellular networks. The present-day algorithms such as Max-Rate, Round-Robin and Proportional-Fair algorithm are getting cast-out in the sprint for providing a dependable solution to this problem in effect with such vast volume of users. We have developed a scheduling algorithm for the receiving stations based upon the fat–time scheduling criteria. The algorithm aims at providing fairness and an increased throughput between mobile stations (having constantly changing channel conditions) by exponentially decreasing or increasing the differential factor of the rate of transmission of data under consistent condition of no noise, or Doppler shift, reflection, diffraction or scattering.**

Keywords*— *Fairness; Throughput; Cellular Networks; Scheduling; Proportional-Fair; Time.

I. Introduction

In an ever expanding set-up of wireless-communications, especially cellular transmission based communications, the need to provide to each and every user, a reliable and effective linkage in terms of greater throughput and increased fairness poses as an emerging challenge. In this paper, we would focus on a wireless scheduling algorithm namely, Proportional Fair scheduling algorithm which is currently in widespread use at the base stations for managing wireless networks of large communication grids. The main idea behind the proportional fair scheduling algorithm is to provide deliverance maintaining a reasonable share of fairness amongst the receiving stations. But when it comes to the issues such as mobility of the stations or fading across the passage of other user stations, the proportional fair scheduling algorithm fails miserably.

We intend to provide an algorithm to overcome such failures, only to take in a better rank of fairness across the whole communication grid, without jeopardizing the throughput deliverance. The proportional fair scheduling algorithm uses a weaker set of parameters to resolve for the instantaneous slot allocation at the base station, i.e. the degree of response/the ability to project a change for these set of parameters is very slow which forms the main reason for the scheduling algorithm for not being able to detect the change in user's channel-conditions spontaneously and thereby provide a response. The proposed algorithm is grounded to provide equilibrium between a diminishing channel condition and an elevating channel condition. It allows on being capable to afford almost the same amount of data transmission rates to the end-users adhering to both the kinds of channel conditions, i.e. good channel conditions and bad channel conditions, under consistency of no noise, or the factors such as Doppler shift, reflection, diffraction or scattering which lead to degradation of the channel conditions for the end-user.

II. Background

A. *Scheduling Algorithms*

The three scheduling algorithms on which we focused upon in this paper are:

1. **Max-Rate**: – Max-rate algorithm focuses on delivering higher throughput where as being unfair in terms of priority handling. It gives high precedence to those users who have good channel condition upon those with a relatively weaker strength. But in terms of evaluation of Fat-time, this algorithm gives an increased by and large network throughput.
2. **Round-Robin**: – Round-robin as it is generally known is the simplest of all scheduling algorithms and can be deployed at almost any scheduling based job. Irrespective of the priority and throughput, it divides the processing capacity into equivalent time cycles to be delivered to every user, episodically. Hence, it is able to provide fairness essentially and a consistent throughput through all scenarios plausible. But the net throughput is low. In terms of implementation also, it is very simple, easy to implement, and starvation-free.
3. **Proportional Fair**: – The proportional-fair algorithm is driven by a check-and-balance strategy between the two challenging aspects of cellular networks: i.e. struggle to maximize the total wireless network throughput while providing all the users with a minimal rank of service. This is done by assigning each data flow a data rate or a scheduling priority (depending on the implementation) that is inversely proportional to its anticipated resource consumption.

B. *Evaluation Parameters*

The parameters that we have used to evaluate and validate the results upon comparison of various scheduling algorithms are:

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1. **Throughput**: – Average rate of successful message delivery over a communication channel. These data may be delivered over a physical or logical link, or pass through a certain network node.
2. **Fairness**: – Fairness is an important consideration in most performance studies. Particularly in distributed systems, where a set of resources are supposed to be shared, a fair allocation is expected. If the throughput of every user is at least as large as that of the other users with the same bottleneck, then the flow control is entitled to be fair.
3. **Fairness Measures** or metrics are used in network engineering to determine whether users or applications are receiving a fair share of system resources. There are several mathematical and conceptual definitions of fairness.
4. **Priority** :– Focuses on the ability for responders to obtain resources from the system network, including, but not limited to:
   a) The process of determining who or what can access (attach to) the network.
   b) The process of determining who or what can initiate traffic on the network.
   c) Process of traffic is scheduling.

III. PROPOSED METHODOLOGY

In order to describe the methodology proposed in this paper, we have first assumed a set of continuous instances of data-rate, say x, for a user. Performing a step wise difference for every n^th and n^th-1data-rate of the instance 'n', we obtain another contiguous set, dx of differential values corresponding to the values of set x.

Let $x = r[t]$; $dx = \frac{dr[t]}{dt}$;

Now, just as acceleration is to speed of a moving object, we introduce another set of differential values, i.e. $d\theta$. It is also the step wise difference between every n^th and n^th-1 value of the set dx. We made the following observations out of the set $d\theta$.

a) If $d\theta_n > 0$, the change of data-rate is going to be positive, i.e. $x_{n-1} < x_n$.

b) Otherwise, the change of data-rate is going to be negative, i.e. $x_{n-1} > x_n$.

Also, a greater value of $d\theta$ depicts a faster rate-change of data rate, i.e. the user's acceleration/deceleration is quick.

The principle we establish for the time allotment relies on the above mentioned effects of values in the set $d\theta$. The inferences thus obtained could be tabulated as the following:

Approaching tower and (symbol +/-)	**Speed ($d\theta$) and (symbol +/-)**	**Time allotment**
Towards (-)	Fast (+)	Give more time
Towards (-)	Slow (-)	Give less time
Away (+)	Fast (+)	Give more time
Away (+)	Slow (-)	Give less time

In order to synthesize our formula, we introduce an exponential constant γ, which should have larger value to allot greater time and vice versa for allotting lesser time in association with the direction of the user with respect to the tower. The table below shall clarify for the intended values of the γ constant.

Approach w.r.t tower	x	dx	γ
Towards	-	+	-
Away	-	-	+
Away	+	+	+
Towards	+	-	-

With the preceeding analysis, we present a formula to calculate a set of values for each user, with a value assigned to each user for each allocation cycle. Based upon these values allocated for each cycle amongst differenct users, the respective cycle is allocated to the user having the greatest value calculated.

$$T = f(r(t)) = \left[\frac{x}{dx[\alpha * d\theta + 1]^{n}}\right]^{\gamma} \qquad (1)$$

The *Components of the formula:*

1. r(t): It is the data-rate at a time instance, say *t*, of a user. It is also depicted by 'x'.
2. $dx = \frac{dr(t)}{dt}$: It is the rate-change of data-rate of a user, with respect to time.
3. $d\theta = \frac{dx}{dt}$: It is the tendency of rate-change of data-rate of a user. It shows if the rate change is in an increasing tendency or a decreasing tendency.

The exponent constants in the above mentioned formula are used to either extrapolate and or limit the resultant value on the basis of a number of factors, such as the distance of the user from the tower, the tendency of $d\theta_n$ and the cumulative effect of rate of change of data-transmission. The following are the descriptions for both the exponential constants:

1. γ: It is the power to the whole ratio-factor (T) and is required to increase or decrease its value. Its value is determined by the product of sign function of x and dx.

$$\frac{[(dx) * x]}{[|x||dx|]}$$

2. n: It is the power to the denominator of ratio-factor (T). It is required to limit the effect of ratio-factor relatively, with respect to the frequency of rate-change of the data-rate of a user. Hence, it is defined as:

$$\frac{d\theta}{|d\theta|}$$

Another constant which has been introduced in the proposed formula is α which could be provided explicitly to induce any correction factors to the values generated by the formula.

IV. Experiments

Before studying about the practical pattern of the signal strength of a receiving station, it is necessary to appreciate another issue with PF algorithm as following. The statistical sequence of signal strength plotted in figure 1 depicts the abrupt changes/impulse of change in the signal strength which recoils back to original signal strength of the station in no time.

A. *Issues*

In order to enumerate the difficulties with the existing scheduling algorithms, we have conducted a series of experiments with the data-rates, the average data-rates, their ratios and time, primarily for two categories of users, i.e. a user pertaining with good channel condition and another user with relatively worst channel condition. This led us to point out towards two issues discretely.

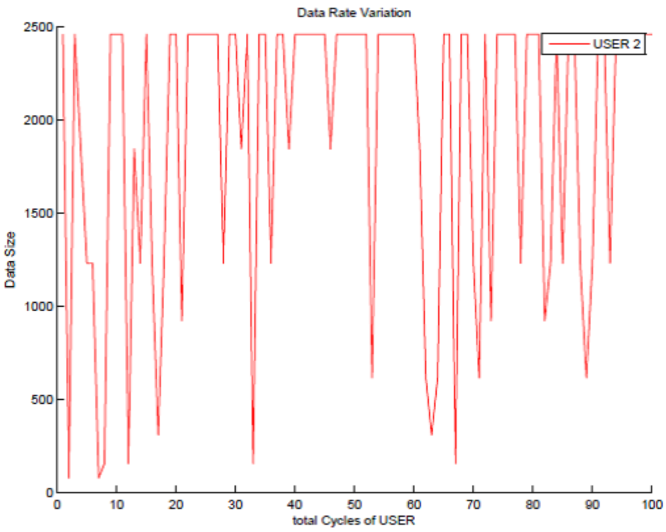

Fig. 1. Bad Channel Condition User

These issues are described with the help of observations obtained by the means of the successive plots. Figure 1, shows the plot for a receiving station with fluctuating channel conditions. They are primarily caused by the motion of the user which has been discussed in the first issue as raised below.

A dip depicts the motion of the user farther from the tower whereas a rise marks the approaching gradient of the user. On the other hand, the second issue to be discussed is focused on the behaviour as shown in the next figure.

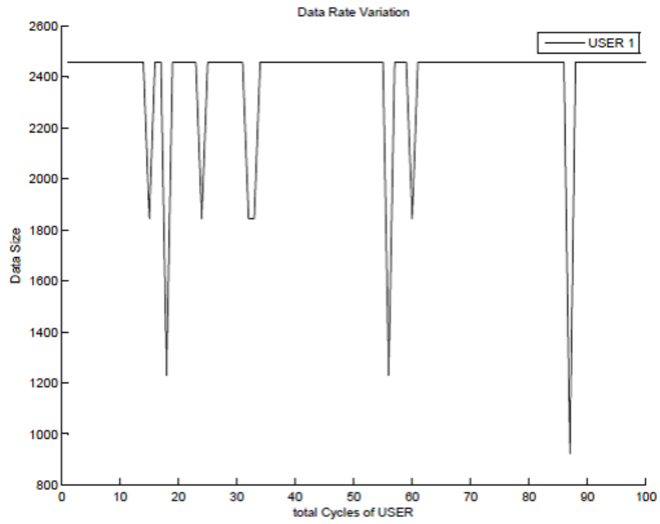

Fig. 2. Best Channel Condition User

Figure 2, shows the plot for a user with healthy channel condition over a period of 100 cycles of relay station. We can observe that the signal strength mostly lays consistently at a data rate of 2457.6 units. The dips which are marked in red ovals are due to the interferences caused by the disturbances or snooping objects which meddle in-between the tower and the user. Such impulses of disturbances must be ignored by the algorithm.

The second issue focuses on the fact that temporary changes in the channel conditions of the user must be ignored by the scheduling algorithm if they are to persist for a very short span of time (cycles). Proportional-Fair algorithm, on a contrary doesn't ignore it but takes into account the temporal aberrations occurring in the channel conditions of the user's signal strength. This in-turn leads to an unwanted shift of priorities, shifting this user station on a lower priority and sometimes leading to starvation. This is fatal for throughput generation by the scheduler.

B. *Causes*

1. *Case 1:*

Figure 3 shows the data rate index for two competing stations moving on the same path, almost in the same trajectory but with different approaching velocities under ideal conditions. The effect of acceleration is clearly visible here when the curve for the index of User 2 surpasses that of User 1 and then again takes a dip. This suggests that User 2 must have approached the transmitting station with a higher velocity than that of User1 and faded-off from the spectrum with even greater velocity. To examine the effect of such competitive scenarios, first let us take a brief look at the data rates of the respective stations:

We have one more user along with the above mentioned two users that are moving on the same path. The 3rd user is made to have a random scenario alongside the other two. We can clearly observe that the users, 1 and 2 have exactly the same data-rate with respect to the corresponding cycles. Hence, we have mentioned them in two different plots.

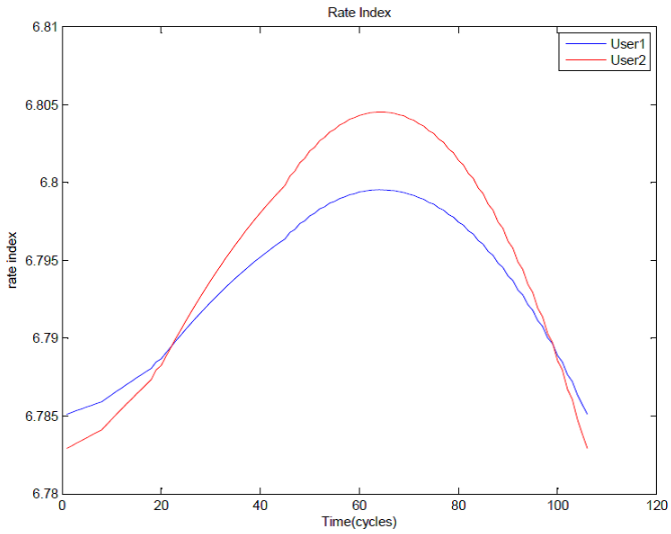

Fig. 3. Rate Index

This pulls us to draw the conclusion that both must be lying on equal priority for the proportional-fair algorithm. But indeed it is not so. The scheduling of slot depends on the ratio of data-rate vs. average-rate; which so ever station has the higher ratio, gets the current slot.

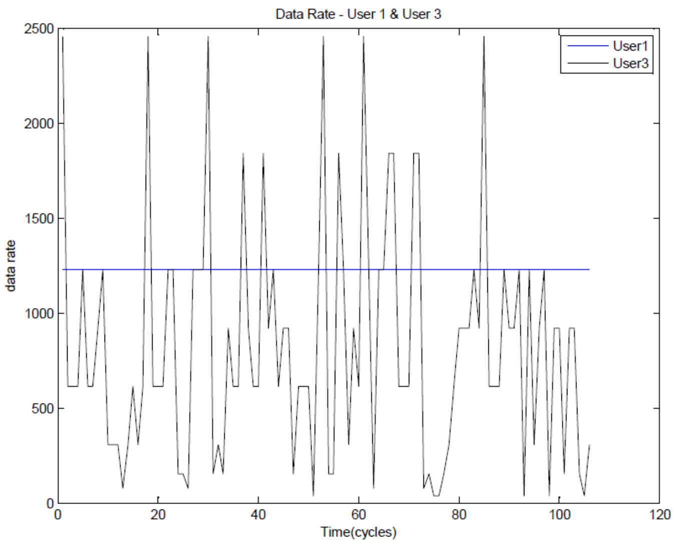

Fig. 4. Data-Rate of User 1 vs. User 3

Hence, for a user which has a dominating data-rate value and subsided cumulative-rate would fetch most of the attention under the slot allocation. The following statistical plot(fig. 6) of the ratio of data-rate vs. average-rate for User 1(good channel condition), User 2 (average channel condition) and random User 3 (bad channel condition) has been given below.

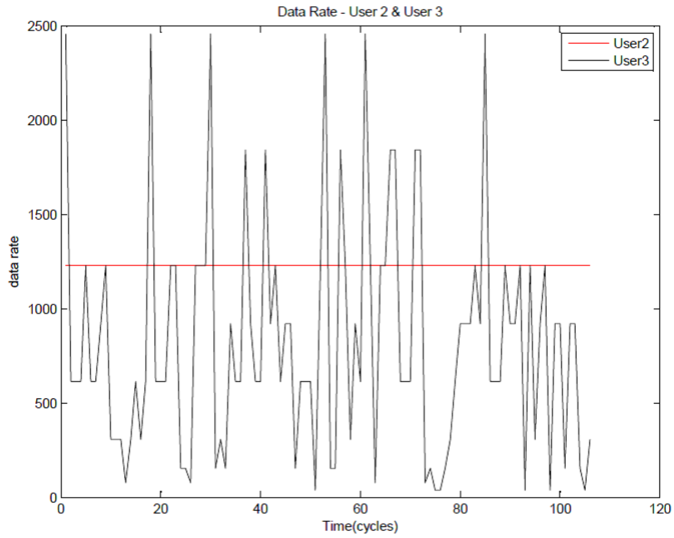

Fig. 5. Data-Rate of User 2 vs. User 3

2. *Case 2:*

We will here consider a case of 3 users, whose channel conditions are a resultant of gamma-random function. Amongst the three users, User 1 has been assigned a range of higher data-rates whereas the other two users, User 2 and User 3 survive in a poor range of channel conditions. This set is clearly visible in the following chart:

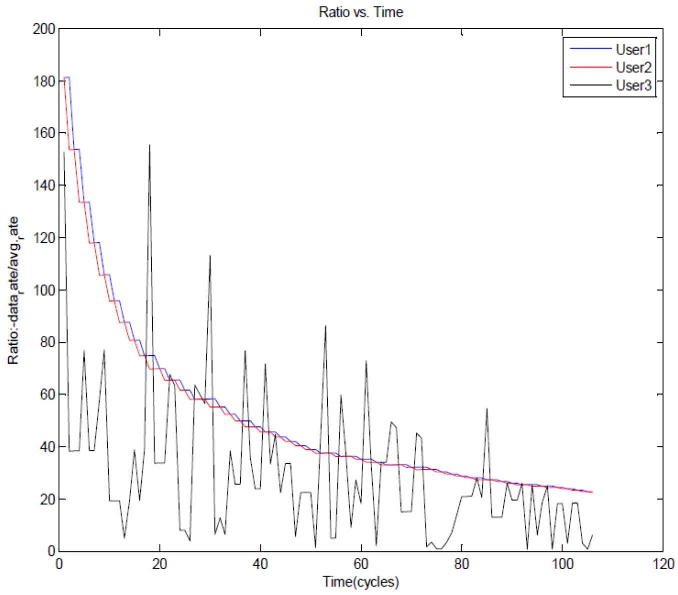

Fig. 6. Data-Rate vs. Average-Rate

In Figure 7, it is evident that User 1 is having a higher data-rate, i.e. best channel-conditions amongst all the three users. Based upon the same set of statistics, let us have a look at the ratio of data-rate vs. average data-rate for the same users: Contradictory to what has been projected by the plot for data-rate; we have an all-time low in the ratio vs. time graph for the User 1.

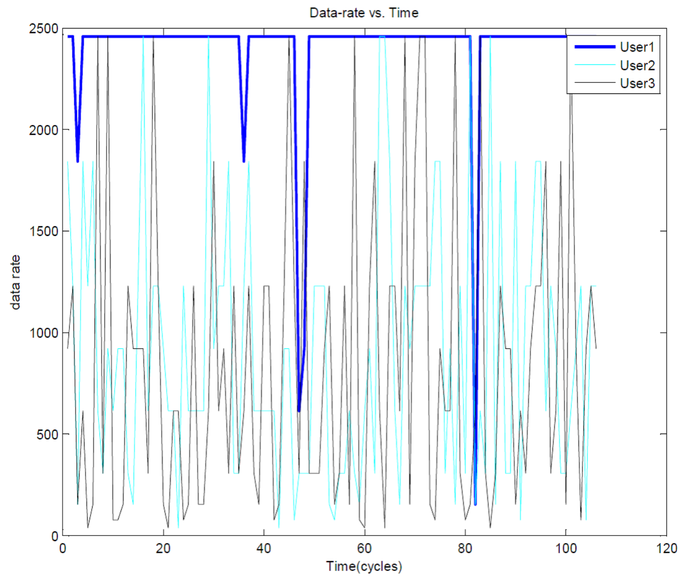

Fig. 7. Data-Rate vs. Time-Plot

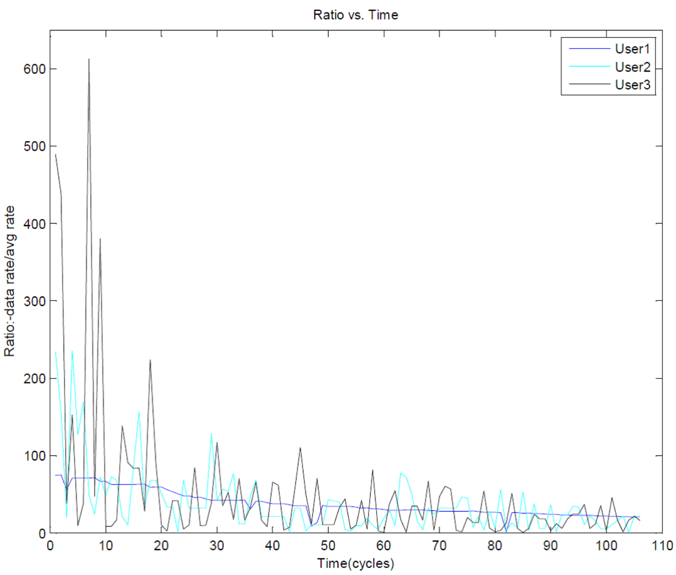

Fig. 8. Data-Rate vs. Average Data-Rate

Since, the allocation under the proportional fair algorithm is entirely based upon the primacy of this data-rate to average-rate ratio; the plot above again suggests a prolonged starvation period for User 1. It is also important to notice that alike as in the case of discrepancy due to mobility, although here, there is only temporary dip in the channel-conditions of the User 1, it is experiencing the same scenario, though in a less severe manner.

V. Result

The effects obtained by this algorithm against the performance of the Proportional-Fair scheduling algorithm could be capitulated in the facts established upon evaluating the performance of both the algorithms on the metric of Fat-Time, as follows:

1. The above proposed algorithm works very efficiently to bring down the total fat-time of the User 3 who is simulating a user continuing a connection under poor channel conditions viz-a-viz User 2 and User 1 who are exhibiting average and good channel conditions respectively.
2. It is important to note that in the process of increasing the share of fairness for User 3, this algorithm does not degrade the metric of fat-time for User 1to substantial fault.
3. It also manages to bring down the cumulative idle-time, i.e. the fat-time for the average user, User 2, as well by 25% approx.

These observations could be easily noticed in Fig. 9, wherein the dotted-line represents the plot for cumulative Fat-Time

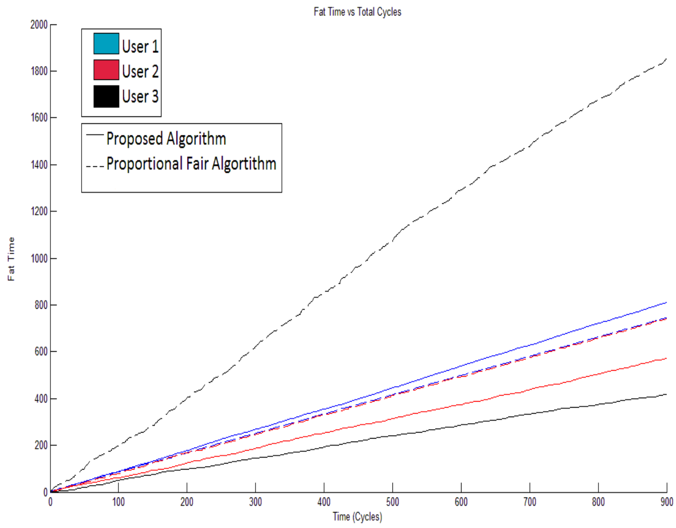

Fig. 9. Fat-Time projections through Proposed-Algorithm and Proportional-Fair Algorithm.

obtained by the use of Proportional-Fair algorithm and the solid-line represents the plot obtained by the use of the Proposed-Algorithm. We can easily observe a decrease of over 25% in the final Fat-Time latency from an approaching 800 to approaching 600 for User 2 and a significant decrease of 76% and above in case of User 3.

VI. CONCLUSION

Traditionally, the study of scheduling policies, such as Round-Robin, Max-Rate and Proportional-Fair, has concentrated on performance metrics such as response time, queue length, tail time and throughput. However, a more equivocal notion of `Fat time' often appears to be equally or more important than these traditional performance metrics.

Based on the concept of Fat-Time, represented statistical evidence provided in this paper proves that the proposed algorithm is founded to balance between a fading channel condition and an upgrading channel condition,without significantly affecting the performance of the user belonging to an upgrading channel condition. Thereby it is being able to provide almost the same amount of data transfer rates to the receieving stations corresponding to all the channel conditions under consistent form or disorder.

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