A Novel Self-Organized Optimization for Wireless Network Nodes CAC Mechanism

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***Abstract*—With the purpose of promoting the network access capacity, it starts with the self-similarity of the wireless network service and then analyzes the relationship among the hurst parameters, the service bandwidth and QoS indicators mathematically. On the basis of the analysis conclusion, a novel self-optimized call admission control mechanism is proposed in order to reduce the bandwidth utilization. And the novel mechanism is achieved and simulated. The results of simulation give the performance comparisons between the novel and traditional CAC in terms of call rejection probability and bandwidth utilization of the aggregated traffic.**

***Keywords*—network self-optimization, call admission control, self-similarity of service, aggregated traffic, service bandwidth optimization.**

I. INTRODUCTION

As the development of the wireless communication technology, the network vendors are faced with a growing challenge posed by the continual reduction in the service charges. In this case, the trend for automation of the network O&M (Operation and Maintenance) is inexorable since it can achieve the network operation with high-quality and low-cost. The management architecture based on SON (Self-Organized Networks) [1] can satisfy this requirement which makes the vendors work intelligently. CAC (Call Admission Control), as an important use case of SON [1] [2] [3], administrates the access of the user's service. The main aim of CAC is to schedule the available resources for new users access with ensuring QoS of the existing call. And the scheduled resources must satisfy the new call's QoS requirement. At present, the main research on the CAC in SON is the use case solution proposed by FP7 SOCRATES project [4]. This solution focuses on the optimization of the resource allocated to the handover calls based on the operator's policy and performance measurement. Although this solution obtains some certain effect, the control process is dependent on the real-time update of the handover threshold, which cannot form the whole network self-optimization. Meanwhile it needs the handover self-optimization use case to achieve the strategy compensatory which is easy to result in the optimization and adjustment conflict [3].

In addition, with the rapid development of the network business, the wireless access network gradually evolves to the all-IP network. Many researches [5] [6] [7] [8] have shown the network service traffic has the self-similarity characteristics, which including the wireless network. However, the existing CAC mechanism in wireless network is mainly based on the Markov characteristic. Although literature [9] presents a flexible P-CAC mechanism based on the self-similarity, it does not discuss the quantitative relationship between the network self-similarity and the boundary of service bandwidth in detail.

To solve these problems in above discussion, this paper firstly analyzes the self-similarity property of the wireless network. And then it gives a novel self-optimized mechanism in SON on the basis of the Hurst parameter. This mechanism considers the self-similarity of the network traffic and has the self-optimized characteristic in large-time-scale. The actual simulation results shows compared with traditional wireless CAC mechanism, the novel mechanism proposed in this paper can reduce the bandwidth utilization and call rejection ratio efficiently.

II. RESEARCH ON THE WIRELESS SELF-SMILARITY AND SERVICE BANDWIDTH

A. Wireless Network Service Self-Similarity

Since literature [10] has proven the traffic produced by the ON/OFF source model has the self-similarity, we use this result to construct the wireless service. we firstly assume the user *m* served by the base station as a source. It will change the state between ON state (send data) and Off state (not send data), which forms a ON/OFF process. For this user, whether it sends data or not at the time *t* can be represented by the sequence $W_m(t)$. $W_m(t)=1$ means the user sends a data packet at the time *t*, whereas $W_m(t)=0$ means the user does not. Assuming the total numbers of the users served by the base station is *M* and time-scale factor is *T*, we can get the cumulative number of packets sent by all the users during the time interval $[0,\ Tt]$:

$$W_M^{all}(Tt)=\int_{t=0}^{Tt}\left(\sum\nolimits_M W_m(u)\right)du \tag{1}$$

For user *m*, its time distribution of ON and OFF state is Pareto distribution with the time expectation μ, time minimal possible value $t_{\min}$ and the heavy tail degree α [10].

Assume the users have the same Pareto distribution for the same service. According to literature [11] we can get the statistical property of $W_M^{all}(Tt)$ as shown in Eq. 2 when *T* is large enough:

$$TM\frac{\mu_{on}}{\mu_{on}+\mu_{off}}t+T^{H}\sqrt{M}kB_{H}(t) \tag{2}$$

where $B_H(t)$ is a Fractional Brownian process and k is finite positive value which is determined by μ, α and $t_{\min}$.

In this equation, mean $TM\,(\mu_{on}/\mu_{on}+\mu_{off})t$ reflects that the traffic varies with the cumulative number of users and time. And the Fractional Brownian process $kB_H(t)$ leads to the burstiness of traffic. Hence, we can see the wireless network service traffic conforms to the characteristic of fractal Brownian [14] from Eq. 8 and reveals the network self-similarity property. H is Hurst parameter which describes the self-similarity degree of the current argument:

$$H=(3\text{-}\alpha_{\min})/2\in(\frac{1}{2},1) \tag{3}$$

where $\alpha_{\min}=\min(\alpha_{on},\alpha_{off})$ .The smaller the $\alpha_{\min}$ is, the heavier the trail of Pareto distribution is. That is to say the larger the Hurst parameter is, the higher the self-similarity of network communication process is.

For the process $W_M^{all}(Tt)$ described by Eq. 2, since it is a stationary process, we can calculate the expectation of $W_M^{all}(1)$ to get the average rate ν of inputting to the buffer system:

$$\nu=E(W_M^{all}(1))=M\frac{\mu_{on}}{\mu_{on}+\mu_{off}} \tag{4}$$

And the coefficient of standard deviation $V\sigma$ is shown in Eq. 5 which reflects the relative fluctuating degree of the traffic burstiness:

$$V\sigma=\frac{\sqrt{Var(W_M^{all}(1))}}{E(W_M^{all}(1))}=\frac{k\sqrt{M}}{\nu}=\frac{k}{\sqrt{M}}\frac{\mu_{on}+\mu_{off}}{\mu_{on}} \tag{5}$$

B. Caculation of the Service Bandwidth with QoS and Hurst parameter

In this part, we discuss the quantative relationship among service rate, overflow and time delay. For a time interval $[t,t+\tau]$, assuming the average system service capability is C and the service policy is FIFO, we can find the length of the buffer queue in the base station $X(t)$ is:

$$\begin{aligned}X(t)&=\sup_{\tau\geq 0}\left[W_M^{all}(t+\tau)-W_M^{all}(t)-C\tau\right]\\&=\sup_{\tau\geq 0}\left[(\nu-C)\tau+\nu V\sigma\Delta B_H(t)\right]\end{aligned} \tag{6}$$

Since $B_H(t)$ is a fractal Brownian process, $\Delta B_H(t)$ has stationary increment and follows the normal distribution with 0 of mean value and τ^H of variance. For Eq. 6, letting $t=0$, since $B_H(0)=0$, then we get the cumulative traffic of the system X_τ :

$$X_\tau=\sup_{\tau\geq 0}\left[(\nu-C)\tau+\nu V\sigma B_H(\tau)\right] \tag{7}$$

If the buffer of the base-station accessing system is b, then the overflow probability ε is:

$$\varepsilon{=}P(X_\tau>b) \tag{8}$$

Then we apply the theorem reserached by Norros [12] [13] to solve the service bandwidth required by the boundary of overflow in the wireless statem station system. Firstly, the overflow probabilty ε satisfies:

$$\varepsilon{=}P(X_\tau>b)\geq\max_{\tau\geq 0}\left[P(W_M^{all}(\tau)>C\tau+b)\right] \tag{9}$$

For fractal Brownian process $B_H(t)$, $B_H(1)$ follows standard Gaussian distribution and $B_H(t)=t^H B_H(1)$, then we have:

$$\varepsilon\geq\max_{\tau\geq 0}\left[\overline{\Phi}\left(\frac{(C-\nu)\tau+b}{\nu V\sigma\cdot\tau^H}\right)\right] \tag{10}$$

By differentiating Eq. 10, we can learn the right side of the inequality achieves maximum value if $\tau=\frac{Hb}{(1-H)(C-\nu)}$. Due to ensuring the quality of service, ε needs to be minimized. Then we get:

$$\varepsilon=\overline{\Phi}\left(\frac{1}{\nu V\sigma}\cdot(\frac{C-\nu}{H})^H\cdot(\frac{b}{1-H})^{1-H}\right) \tag{11}$$

Note that the difference with the traditional research is that we do not employ any approximations for the Gaussian distribution. Because of the high-precision of industrial-grad for calculating this, the approximations may lead to the deviation on the final result. According to Eq. 11 we can find the service bandwidth $C(\varepsilon,H)$ which meets the requirement on the overflow probability.

$$C(\varepsilon,H)=\nu+H\left[(\frac{b}{1-H})^{H-1}\nu V\sigma\overline{\Phi}^{-1}(\varepsilon)\right]^{1/H} \tag{12}$$

Then we solve the quantitative relationship among average length of queue and time delay. From Eq. 6 and Eq. 11 we can know the cumulative probability distribution $F(X_\tau<x)$ of the random variable X_τ which inputs to the system is:

$$F(X_\tau<x)=\Phi\left(\frac{1}{\nu V\sigma}\cdot(\frac{C-\nu}{H})^H\cdot(\frac{x}{1-H})^{1-H}\right) \tag{13}$$

Let $f(x)$ is the probability distribution function of Eq. 13. Then we can find the average length of the queue which is the mean of X_τ :

$$B{=}E(X_\tau){=}\int_0^b x\cdot f(x)dx{=}K_1K_2^H\int_0^b x^{K_2}e^{-\frac{(K_1K_2^{-K_2}x^{K_2})^2}{2}}dx \tag{14}$$

where $K_1=\frac{1}{\nu V\sigma}\cdot(\frac{C-\nu}{H})^H$ and $K_2=1-H$.

And the average time delay of the system is:

$$T_d=B/C \tag{15}$$

From Eq. 15, we can also get the service bandwidth $C(T_d,H)$ which required by the time delay.

C. Applying to the Aggregated Traffic

In the actual network, we may conduct the network optimization work in the sink node whose traffic comes from serveral base stations. The traffic in this condtion aggregates from some desperate traffic flow. Our research work above is focusing on one traffic flow, we need to expand the theoritical results to apply to the aggregated traffc. Hence, we give the following theory.

Theory: Assuming $W(1,t)$, $W(2,t)$, $W(3,t)$, ..., $W(N,t)$ are N uncorrelated self-similarity ON/OFF processes for random variables W_1, W_2,…, W_N. And $W(n,t)$ for n=1,2,3,...,N can be represented by Eq. 5:

$$W(n,t) = TM\frac{\mu_{on}}{\mu_{on} + \mu_{off}}t + T^{H_n}\sqrt{M}kB_{H_n}(t) \qquad (16)$$

where H_n is the Hurst parameter for the self-similarity traffic flow $W(n,t)$. The expectation of $W(n,t)$ is v_n and the standard deviation is $V\sigma_n$.

Define $W(t)=\sum_{n=1}^{N} W(n,t)$ is the aggregated process of $W(1,t)$, $W(2,t)$, $W(3,t)$, ..., $W(N,t)$. Then the service bandwidth of W for overflow and time delay are $C(\varepsilon,H_{\max})$ and $C(T_d,H_{\max})$ where $H_{\max} = \max(H_1, H_2, ..., H_N)$.

Proof: we firstly prove this theory for the aggregated traffic of arbitrary two traffic flows $W(n,t)$ and $W(n-a,t)$ where a is a positive value which is smaller than n. We can solve the correlation coefficient $r^{2n-a}(k)$ of the aggregated traffic flow $W^{2n-a}(t) = W(n,t) + W(n-a,t)$:

$$r^{2n-a}(k) = = \frac{V\sigma_n^2}{V\sigma_n^2 + V\sigma_{n-a}^2} r_n(k) + \frac{V\sigma_{n-a}^2}{V\sigma_n^2 + V\sigma_{n-a}^2} r_{n-a}(k) \qquad (17)$$

Since $W(n,t)$ is a self-smilarity ON/OFF process of random variable W_n, then we have $r_n(k) \sim c_n k^{2(H_n-1)}$ as $k \to \infty$ where c_n is a constant in (0, ∞). If $H_n > H_{n-a}$, then $H_{\max} = H_n$, So for Eq. 17, we have

$$\begin{aligned}\lim_{k\to\infty}\frac{r^{2n-a}(k)}{k^{2(H_{\max}-1)}} &= \frac{V\sigma_n^2}{V\sigma_n^2 + V\sigma_{n-a}^2} c_n + \frac{V\sigma_{n-a}^2}{V\sigma_n^2 + V\sigma_{n-a}^2} \lim_{k\to\infty} c_{n-a} k^{2(H_{n-a}-H_n)} \\ &= \frac{V\sigma_n^2}{V\sigma_n^2 + V\sigma_{n-a}^2} c_n = c' \qquad (18)\end{aligned}$$

which means $r^{2n-a}(k) \sim c' k^{2(H_{\max}-1)}$ as $k \to \infty$. We can get the similar result for the case that $H_n < H_{n-a}$. Therefore the aggregated traffic of arbitrary two traffic flows $W(n,t)$ and $W(n-a,t)$ is a self-similarity process with Hurst parameter $H_{\max} = \max(H_n, H_{n-a})$. By this method, we can get the overall aggregated traffic $W(t)$ is a similarity process with $H_{\max} = \max(H_1, H_2, ..., H_N)$. By Eq. 12 and Eq. 15 we can find the service bandwidth of W for overflow and time-delay are $C(\varepsilon, H_{\max})$ and $C(T_d, H_{\max})$ respectively.

Then we go to the discussion on the self-optimized CAC mechanism which can improve the access capacity according to these properties.

III. SELF-OPTIMIZED CAC MECHANISM

Since the wireless service has the characteristic of time-varing and user-depending, it reveals the burstiness of the network traffic at the different time period, which represents the different self-simlarity property. This paper proposes a novel mechanism for this case. The novel mechanism achieves the self-optimization of the service bandwidth based on the Hurst parameter and QoS requirement. Compared with the traditional optimiziton of the system parameters, the novel mechanism has the property of self-organized in the large time-scale and can copy with the future wireless packet service (such as IP voice, high-speed downloading and so on) with higher burstiness because it is based on self-similarity property. The workflow of the new mechanism is shown as follows:

Step 1: This mechanism needs to continually monitor the cell traffic status by OAM/SON functional entity to detect whether the Hurst parameter changes or not. This centralized method is easier for the realization than the distributed method in SON. Considering the low complexity required by the implementation of self-optimization, this paper employs V-T method which uses the variance-time curve-fitting to estimate the Hurst parameter.

Step 2: If the hurst parameter changes, according to the current value of hurst parameter and QoS of each service, it calculates the service bandwidth of the related indicator via the method described as above. Then it gets the optimal bandwidth of each service, which equals the minimal bandwidth that can meet the requirement of the QoS according to the Hurst parameter. For the solution on this optimal bandwidth, we use the PHR algorithm which is proposed by Rockfellar[14].

Step 3: Then OAM/SON entity updates this optimal bandwdithd for the related cell-level access control parameter. The cell will assign the updated optimal bandwidth to the accessing user in accordance with the type of arriving service. Then the process of normal CAC is carried out. Next go to Step 1.

IV. SIMULATION RESULTS

Firstly we establish the base station service model of M served users and 20M overall service bandwidth. Each user adopts ON/OFF model to send packets of IP voice, low speed data service (100kbps) and high speed data service (300kbps) respectively. Being different with some research works [8] [14], some parameters of the ON/OFF model here are not fixed but random changing in order to simulate the actual network status which means the burstiness of traffic varies with the time.

Figure 1 gives the call rejection ratio comparison between the novel and traditional CAC for different number of served users in one base station. From the figure, we can learn the call rejection ratio of the 3 services in the novel method are all lower than in the traditional CAC in the case of high traffic loads, especially for the data service. Moreover, as the number of served users increasing, the effect of the novel method is more and more obvious. This is because if the Hurst parameter changes, sometimes it is easier to satisfy the quality of service as discussed above. For the high-speed data service, since its high bandwidth demand, the effect of the calculated optimal bandwidth is more obvious in accordance with the constraint on the self-similarity property.

Figure 2 shows the bandwidth utilization (BWU) of the aggregated traffic comparison between the novel and traditional CAC. The aggregated traffic comes from 6, 9 and 12 base station traffic flows respectively. The BWU here is the ratio of sum service bandwidth of the separate traffic flow to the overall BW in the aggregated nodes. From the figure, we can see the BWU of the novel CAC is lower than in traditional CAC, which verify the theorem discussed above.

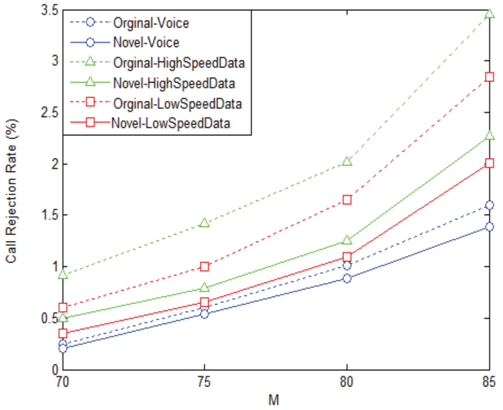

Fig. 1. Call rejection ratio comparison between novel and traditional CAC

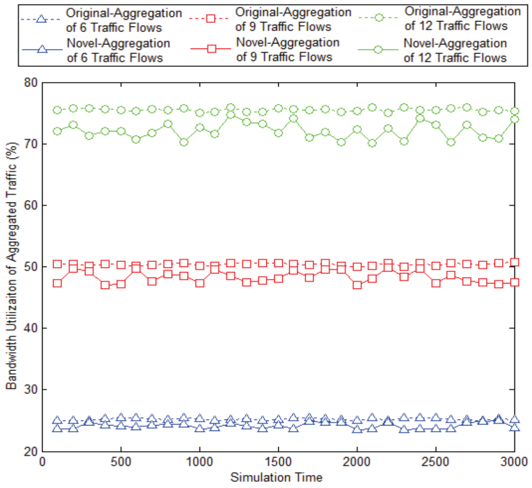

Fig. 2. Bandwidth utilization of the aggregated traffic comparison between novel and traditional CAC

V. CONCLUSION

This paper mainly has three 3 contributions: 1) It researches on the wireless network self-similarity service by using ON/OFF process to model the user's behavior. 2) The quantitative relationship between Hurst parameter and QoS (bandwidth, delay and overflow) is shown if not use the approximate process which is different with litteral [13] and [15]. 3) Based on the anlysis on these characteristics, a novel self-optimized CAC mechanism is proposed. And the results of simulation work show the novel mechanism can reduces the BWU and call rejection ratio of the network service effectivley compared with the traditional CAC. The further research work is mainly conducted in the perspective of the research on the multi-usecases coordinated CAC mechanism from the viewpoint of handover and multi-stations joint optimization.

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