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Self-organizing Load Balancing for Relay Based Cellular Networks

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***Abstract*—A self-organizing load balancing framework is proposed in this paper. It provides self-optimizing load balancing policies to improve adaptation and robustness of Fixed Relay Station (FRS) based cellular networks. The framework proposes a Self-organizing Cooperative Partner Cluster (SCPC) concept to dynamically select optimal partners of each BS and RS. A novel Comprehensive Load Balancing Policy Stack (CLBPS) is also proposed to utilize merits of various load balancing policies. Load balancing performance, signaling costs and user experience are taken into account in both SCPC and CLBPS. Simulation results show that the call blocking rate is reduced and the network throughput of FRS networks is improved.**

Keywords—Self-organizing network (SON), Self-optimizing, Fixed Relay Station (FRS), Load balancing (LB).

I. INTRODUCTION

Driven by users' demands on high data rate and seamless coverage, the deployment and maintenance of mobile networks are becoming more and more complex and expensive. Such challenges can be tackled through the exploitation of self-organization network (SON) [1]. SON aims at improving network performance and reducing costs of configuration and management by simplifying operational tasks through automated mechanisms such as self-configuration, self-optimization and self-healing functionalities [2][3]. The Third Generation Partnership Project (3GPP) has setup SON group for LTE/LTE-A networks [4]. Many other organizations or projects such as Next Generation Mobile Networks (NGMN) [5], European commission FP7 (The Seventh Framework Programme) E3 project and FP7 SOCRATES project [6][7] work on key technologies of SON. However, the current SON research work focuses on single-hop cellular networks.

Load Balancing (LB) aims at efficiently making use of the limited spectrum to deal with unequal loads in order to improve network reliability by reducing the congestion probability in hot spot areas of cellular networks. Load balancing is one of the key use cases in SON [4]. Four standalone load balance policies, e.g. transmit power adjustment, antenna parameters adjustment, cell reselection, and handover parameters adjustment, are proposed in [8][9]. Load based handover and cell reselection optimization are also proposed by 3GPP [10] and NGMN [11]. However, these research works mainly focus on identifying technique requirements and relevant load balancing policies and there have been little publications with simulation results.

From the network architecture point of view, to achieve seamless coverage and higher data rate, Fixed Relay Stations (FRS) [12][13] have been considered as a promising candidate technology in LTE-Advanced and IEEE 802.16j/m. However, traditional load balance schemes for FRS based cellular networks [14]-[17] only consider standalone policy. Most of these standalone mechanisms take centrally controlled approach for selecting load balancing partners. Only a few schemes of FRS network have the self-organization functionality. Since SON LB and FRS LB have been investigated separately, the combination of FRS LB with self-organizing functionality could greatly improve FRS network performance and decrease costs of configurations and optimization. Hence, a self-organizing LB framework for FRS based cellular networks is proposed.

There are several drawbacks of the centrally controlled partner selection approach used in current FRS networks. It imposes longer delay, higher signaling overhead and requires intensive information to be available at the central control unit. To overcome these shortcomings, a Self-organizing Cooperative Partner Cluster (SCPC) concept is proposed in this paper and the LB partner selection and updating process are distributed controlled rather than centrally control. This improves the robustness and the scalability of networks. Simulation results show that the sub-optimization with limited local information for distributed control can achieve satisfactory performance in terms of LB efficiency.

Current SON load balancing (LB) mechanisms for single-hop cellular network are not suitable for FRS cellular networks because of the complex network structure and high signaling costs after adding additional relay stations (RS). Taking 3GPP SON load balancing based handover [10] as an example, it only considers the load differences among BSs. However, there are five types of handover in FRS networks [17]: Intra-cell RS-RS, Intra-cell BS-RS, Inter-cell BS-BS, Inter-cell RS-RS and Inter-cell BS-RS handover. The two intra-cell handovers have less signaling cost than the three inter-cell handovers. Both handover latency and service interruption time are different among five handover types. So, designing appropriate SON LB weight for different LB partner and LB scenarios in FRS network could greatly improve both network performance and user experience with low signaling cost. One contribution of this paper is designing a self-organizing load balancing framework, which utilizes the signaling costs and user experience as key factors rather than only considering load difference of previous SON LB.

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In addition, the current SON employs standalone LB policy, but each policy has its advantages and disadvantages. For example, both channel borrowing and resource reservation policy are easy to implement with low signaling cost [14], but their LB efficiency is not as outstanding as handover because available resources are limited for borrowing and reservation. Handover could distribute unequal traffic to other non-congested neighbor partners, so it could balance load to a larger extent, it, however, introduces handover latency, dropping, signaling overhead [17]. One contribution is proposed Comprehensive Load Balancing Policy Stack (CLBPS) adaptively selects single LB policy or combines multiple policies according to network condition, in this way, it could utilize the merit of each policy, rather than standalone and fixed policy of tradition SON LB.

As the process of key CLBPS, it defines LB objective according to limited network condition information and partner information in SCPC. Then CLBPS adaptively selects suitable single LB policy or combines multiple policies into joint LB policies and define the trigger and objective of each policy. Finally CLBPS comprehensively considers LB performance, signaling costs and user experience factors to adjust the parameters of each policy. CLBPS could guarantee high network performance, low signaling costs, high degree of user satisfaction. In additional, it has low computational complexity.

The rest of the paper is organized as follows. The proposed self-organizing LB framework is presented in section 2. In section 3, we focus on self-optimization and detail illustrated a sequential self-optimization load balancing policy stack to exemplify the framework. The simulation result is shown in section 4. The paper is concluded in section 5.

II. SELF-ORGANIZING LOAD BALANCING FRAMEWORK

A. Self-organizing Load Balancing Framework Overview

This paper proposes a self-organizing load balancing framework aims to improve adaptation, robustness and scalability of FRS based cellular networks. Each BS and RS node equips with its self-organizing load balancing framework, shown as Figure 1.

The optimization loop is composed of measurements via network monitoring, exchange of information between neighbors for setting up load balancing partners, LB policy/policies selection and implementation, network optimization, performance evaluation feedback.

In the optimization loop, firstly, measurement module detects its own new call blocking probability, the handover dropping with each neighbor BS or RS node. The measurement reports and performance indicators are then transmitted to the Self-organizing Cooperative Partner Cluster (SCPC) module where neighbor nodes exchange temporary load ratio and load status, available resources and node identity information to identify their partners and update their SCPC.

Once the partner clusters are set up, each cluster uses the Comprehensive Load Balancing Policy Stack (CLBPS) to make decision on which LB scheme/s to adopt based on the current available information and the network condition. The decision could be a single LB policy or sequentially or parallelly triggered multiple policies. Then the CLBPS calculates the parameters of selected policy/policies. If a BS or RS suffers from fault, automated fault detection will trigger self-healing, which utilizes the above CLBPS to transfer the original connection of the fault node to its partners in SCPC, then updates related SCPCs accordingly.

Following the policy decision, the selected optimal single or joint LB policies and their parameters are implemented in FRS networks.

The effects of the self-organizing LB are evaluated by monitoring several performance indicators, including user experience and network performance indicators, such as network throughput, new call blocking rate and the handover dropping probability. The evaluation reports are fed back to the self-optimization and self-healing module for further adjustment if needed.

In order to reduce processing delay and computational complexity, machine learning, such as Case Based Reasoning, can be used to record the SCPC information, relevant LB policy selection and parameters adjustment results corresponding to the specific network scenarios.

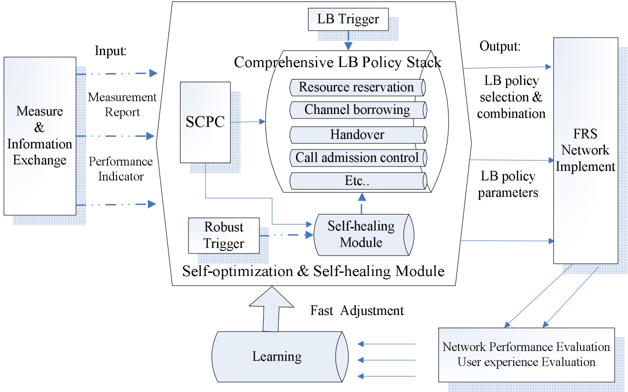

Fig.1 Self-organizing Load Balancing Framework Architecture

B. Self-optimizing Cooperative Partner Cluster (SCPC)

Distributed control FRS network demands for online and adaptive partner selection and update based on current network condition, so a novel Self-organizing Cooperative Partner Cluster (SCPC) is proposed. Each node, which can be a BS or RS, has its SCPC, but not all nodes in the network can be selected as partners in SCPC, and partners need to meet three conditions.

(1) The pilot coverage overlap of target node will decide whether a BS or RS is the neighbor nodes of target node, neighbor node is the basic condition of being a partner.

(2) With exchanged information between neighbor node and target node, including temporary load ratio, load status (light load/ordinary loaded/ heavy loaded/ overloaded), residual resources and node identity information, partners should also meet following general rules.

- Partner's load ratio, which equals the used resource to total resource, cannot exceed load ratio of target node.
- Partner's load status cannot aggravate after load balancing. e.g. Aggravating from ordinary load to heavy load status.

(3) Partners further need to meet related policy rules. Take handover policy as an example, through detecting the handover dropping with neighbor nodes in measurement module, neighbor node, which suffers high handover dropping probability with target node will not be selected as partner.

Only nodes achieve all neighbor nodes rule, general rules, and policy rules can be select as partners in SCPC.

In SCPC, novel factors, including signaling cost and complexity, user experience of load balancing policies are also considered as key factors. The SCPC doesn't incur intra-cell or inter-cell constraint, and it could provide online and adaptive LB partner list thereby to assist CLBPS module to get better load balancing optimization performance. Meanwhile, SCPC will assist network recovery of self-healing functionalities.

C. Comprehensive Load Balancing Policy Stack (CLBPS)

A Comprehensive Load Balancing Policy Stack (CLBPS) is proposed for the self-optimization load balancing process. It integrates a series of load balance policies, such as resource reservation, channel borrowing, handover, call admission control, antenna control and coverage adjustment. To exemplify this framework, three load balancing policies are chosen, i.e. Channel Borrowing (CB), Resource Reservation (RR) and Handover (HO).

- First, CLBPS of each node defines its overall LB objective according to its load ratio and load status as well as partners' load information in SCPC.
- Second, CLBPS adaptive selects suitable single LB policy or combine multiple policies into joint LB policies, rather than standalone and fixed policy in previous SON LB, which is also one contribution of this paper. The joint LB policies are implemented in sequential order or in parallel order between node and its different partners.
- Third, CLBPS sets relative trigger of different policies according to node's load information, its partners' information and signaling cost policy in SCPC. For example, reserved resource allocation utilizes reserved channel, and channel borrowing utilizes idle resource of partners in SCPC. These two policies deals with unequal traffic with low signaling costs while minimizing the unnecessary handover, and in this way, decrease handover failure and dropping, so they are more likely to have lower trigger threshold than handover.
- Fourth, once trigger threshold is reached, for both single policy and joint LB policies, CLBPS defines each policy's load balancing objective and calculate detail policy parameters according to network condition.

To exemplify self-healing process, a unified channel borrowing and handover mechanism is triggered to tackle sudden RS or BS invalidation like power-less. CLBPS lends spectrum from failure node to its SCPC partners and then triggers relative handover process. The flowchart of CLBPS is shown in Figure 2.

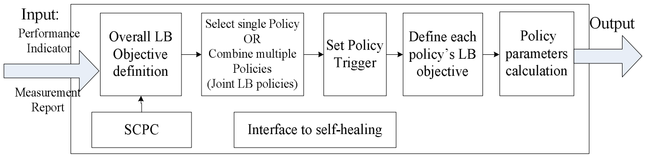

Fig.2 Comprehensive Load Balancing Policy Stack (CLBPS) flowchart

III. SEQUENTIAL SELF-OPTIMIZATION LOAD BALANCING POLICY

To exemplify above proposed framework, especially SCPC and CLBPS, assumes CLBPS adaptively combine Channel Borrowing (CB), Resource Reservation (RR) and Handover into a joint LB policies: sequential self-optimization load balancing policy.

A. System model& LB parameter definition

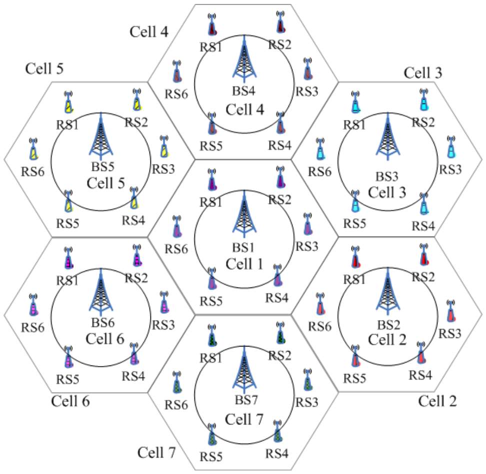

Fig.3 Fixed Relay Station based cellular network model

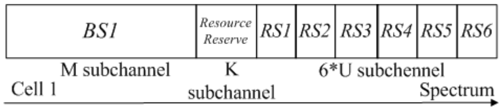

Fig.4 Spectrum initialization planning diagram of cell 1

The FRS network model and initial frequency planning are shown in Figure 3 and Figure 4. *The* frequency planning adds the reserved spectrum in that of reference [18]. It has assumed that all cells utilize the whole available spectrum to ensure high spectrum efficiency, and the total available sub-channels available are divided into three orthogonal sets Q_{RS}, Q_{BS} and Q_{RR}, Q_{BS} and Q_{RR} of M and K sub-channels respectively. Each RS contains U sub-channels and there are $6*U$ sub-channels in total for Q_{RS} set as shown in Figure 4.

Each node's CLBPS defines its own load balance trigger set. This section denotes the load balancing object as node i, which can be a RS or BS, and its trigger set $Trigger_{-i}$ includes $\{T_{RR-i}\ ,\ T_{CB-i}\ ,\ T_{HO-i}\ \}$. When load ratio of node i reach each trigger, relative policy will be triggered. To minimize handover failure, the triggers hold:

$$T_{RR-i} < T_{CB-i} < T_{HO-i} \tag{1}$$

The equation (1) guarantees that the reserved sub-channels are allocated to node i firstly. If load ratio of node i continues to increase and reach T_{CB-i}. The unused resource from partners in SCPC will be borrowed. Above two policies could decrease load ratio of RS to some extent, but if its load ratio reaches T_{HO-i}, the HO optimization will be trigger finally.

The following utilize initial load balancing ratio and real load balancing ratio:

- Initial load ratio: It indicates the ratio of current used resources to initial available resources in spectrum initialization stage.
- Real load ratio: It indicates the ratio of current used resources to all current available resources, which include both the borrowed resource from partners and the assigned resources from reserved spectrum.

B. Self-organizing Cooperative Partner Cluster selection & update

Provided the Self-organizing Cooperative Partner Cluster (SCPC) of node *i* contains *J* partners. Node *i* is also the partner of other *Z* nodes, we define:

- N_{Init-i} : Initial resources available in spectrum initialization stage of node *i*. If the type of node *i* is BS, N_{Init-i} is *M*; and N_{Init-i} is *U* if the type of node *i* is RS.
- K_{RR-i} : Assigned resources from reserved spectrum.
- $N_{CB\ i-j}$: Borrowed resources from its partner *j*.
- $N_{CL\ z-i}$: As a partner of other BS or RS in the network, node *i* also lends its channel resources to node *z*. It depicts the Channel Lending (CL) resource to node *z* from node *i*.
- N_{Use-i} : Current used resources of node *i*.

So the initial load ratio L_{Real-i} equals:

$$L_{Init-i} = N_{\text{Use-i}} \big/ N_{Init-i} \tag{2}$$

The real load ratio L_{Real-i} equals:

$$L_{\text{Re}al-i} = N_{\text{Use-i}} \big/ (N_{Init-i} + K_{RR-i} + \sum_{j=1}^{J} N_{CB\ \text{i-j}} - \sum_{z=1}^{Z} N_{CL\ \text{z-i}}) \tag{3}$$

To simplified the process, the rest of the paper takes RS3 of Cell 1 as node *i*.

Since partners in SCPC lends its channel to RS3 in Cell 1 or change handover margin to RS3, inappropriate SCPC selection increases partners' load greatly, e.g. their load status aggravate. For example, partners' load status aggravates from normal load to heavy load after lending its channel to node *i*, and then the partner triggers load balancing policy, so that the single load balance becomes iterative load balancing in multiple BS and RS nodes. This increases signaling cost and decreases network performance.

To avoid this, three rules in SCPC are integrated in our framework.

- First, partner's load ratio cannot exceed target BS or RS's load ratio, namely:

$$L_{real-j} < L_{real-i} \qquad j \in [0,1,...J] \tag{4}$$

- Second, partner's load status cannot aggravate after load balancing.
- Third, different weights are allocated to different partners. Weight indicates the signaling cost and complexity as well as user experience to implement load balancing policy as shown in Table 1, 2.

For example, RS3(Cell1) has five partners and its SCPC is shown in Table 1. The signaling costs and user experience based weight is set based on different partner and policy.

Table 1 Self-organizing Cooperative Partner Cluster table of RS3(C1)

ID (*j*)	Node N.O.	Cell N.O.	Real load ratio	Load status	Active status	Weight
1	RS 6(C3)	Cell3	20%	Light	Active	Based on signaling costs, user experience of policy
2	RS 1(C2)	Cell2	38%	Normal	Active	
3	RS 2(C1)	Cell1	43%	Normal	Active	
4	RS 5(C3)	Cell3	46%	Normal	Active	
5	BS1 (C1)	Cell1	53%	Normal	Active	

C. Comprehensive Load Balancing Policy Stack

This section introduces implement of exemplified three sequential policies in CLBPS. They are triggered according to

$$L_{real-i} < Trigger_{-i} \qquad Trigger_{-i} \in \{\mathrm{T_{RR-i}}, \mathrm{T_{CB-i}}, \mathrm{T_{HO-i}}\} \tag{5}$$

According to equation (1) (5), if load ratio of node *i* increases continuously, the reserved resource allocation, channel borrowing and handover will be triggered sequentially.

(1)Allocating Reserved Resource

Because reserved sub-channel can be used by any RS or BS, and all cells have the same initial frequency planning, to simplify the inter-cell interference coordination, the, reserved sub-channels in each cell can only be assigned to BS or RS of its own cell, and cannot be assigned to nodes in other cells.

Because of above intra-cell RR allocation restriction, the reserved sub-channels are the shared resources among all nodes in one cell. Once reserved resource allocation is triggered, CLBPS defines the LB objective L_{RR-i} according to its own cell's BS and RS load ratio, taking RS3 of Cell 1 for example.

$$L_{RR-RS3(C1)} = (\sum_{p=1}^{6} L_{Real-RS\ p(C1)} + L_{Real-BS1})/7 - H_{RR-i} \tag{6}$$

Where H_{RR-i} is the Resource Reservation (RR) allocation hysteresis to avoid frequent RR allocation request.

$$K_{RR-i} = \frac{N_{\text{Use-i}}}{L_{RR-i}} - N_{Init-i} \tag{7}$$

Then, CLBPS calculates the total RR sub-channels of allocating to node *i* K_{RR-i} according to equation (7). And above process has low computation complexity.

(2)Channel Borrowing

Unlike the above reserved resource allocation, once channel borrowing is triggered, CLBPS defines L_{obj-i} according to SCPC as shown in equation (8)..

$$L_{obj-i} = L_{CB-i} = (\sum_{j=1}^{J} L_{Real-j} \Big/ J) - H_{CB-i} \tag{8}$$

where *J* is the total number of partners in SCPC. H_{CB-i} is the channel borrowing load hysteresis, which is to avoid frequent channel borrowing operation. According to (9), CLBPS will calculate the total required borrowing sub-channel from partners in SCPC, namely $N_{CB\ \text{i-SCPC}}$.

$$N_{CB\ \text{i-SCPC}} = \frac{N_{\text{Use-i}}}{L_{CB-i}} - K_{RR-i} + \sum_{z=1}^{Z} N_{CL\ \text{z-i}} - N_{Init-i} \quad (9)$$

Note. $N_{CL\ \text{z-i}}$: The node *i* lending resource amount to node *z* because node *i* may be selected as other node's SCPC partner.

After $N_{CB\ \text{i-SCPC}}$ calculation, CLBPS decides how to lend each partner's (denotes as partner *j*) channel to node *i*. In this process, firstly, CLBPS calculates each partner's total number of available lending resource according to their load ratio L_{real-j} and $Trigger_{-j}$. The channel borrowing meets:

$$N_{CB\ \ i-j} < MaxN_{CL\ \ -j} \quad (10)$$

where $MaxN_{CB\ \ i-j}$ is the mentioned total number of available lending resource from partner *j*. Equation (10) guarantees that the load status of partner *j* does not aggravate after lending channels. Then $N_{CB\ \ i-j}$ is calculated according to SCPC, and this process has low computation complexity.

(3)Handover

The handover has highest trigger threshold than other two policies as shown in formula1. Once handover is triggered, node *i* suffers seriously heavy load, or even overloaded.

In Table1, SCPC selects partners for RS3 in Cell1, so there exists three handover (HO) scenarios: Inter-cell RS-RS HO, Intra-cell RS-RS HO, and Intra-cell RS-BS HO. The signaling costs, HO latency and service interruption time caused by HO is different among three scenarios. To minimize HO failure and decrease signaling costs, novel Handover Weight will be set as Table 2.

According to [17], both Intra-cell RS-BS and Intra-cell RS-RS HO are less likely to drop. Intra-cell RS-BS HO can easily control and extra signaling like automatic retransmission request (ARQ), L3 address renewal, inter-BS signaling are not required, so $W_{\text{Intra-cell RS-BS}}$ is set highest value. Intra-cell RS-RS HO also does not require inter-BS signaling, but ARQ should be consistent between serving RS and target RS, which requires extra signaling, so $W_{\text{Intra-cell RS-RS}}$ sets medium value.

Inter-cell RS-RS HO causes larger signaling overhead because it requires inter-BS signaling, RS-BS signaling in both cells, the ARQ status and the L3 address management are also required. In addition, the channel quality of the terminal in this handover region can be seriously attenuated by the inter-cell interference. So it sets the lowest weight value to minimize Inter-cell RS-RS HO.

Table 2 Handover Weight in SCPC of RS3(Cell1)

ID (*j*)	Node N.O.	HO scenario	HO Weight $W_{HO\ i\text{-}j}$
1	RS6(Cell3)	Inter-cell RS-RS HO	$W_{\text{Inter-cell RS-RS}}$ Lowest
2	RS1(Cell2)	Inter-cell RS-RS HO	$W_{\text{Inter-cell RS-RS}}$ Lowest
3	RS2(Cell1)	Intra-cell RS-RS HO	$W_{\text{Intra-cell RS-RS}}$ Medium
4	RS5(Cell3)	Inter-cell RS-RS HO	$W_{\text{Inter-cell RS-RS}}$ Lowest
5	BS1 (Cell1)	Intra-cell RS-BS HO	$W_{\text{Intra-cell RS-BS}}$ Highest

CLBPS defines L_{HO-i} according to Handover Weight and real load ratio in SCPC:

$$L_{obj-i} = L_{HO-i} = \left(\sum_{j=1}^{J} W_{HO\ i-j} \bullet L_{Real-j} \Big/ \sum_{j=1}^{J} W_{HO\ i-j}\right) - H_{HO-i} \quad (11)$$

where H_{HO-i} depicts the handover load hysteresis to avoid frequent load balancing based handover operation.

CLBPS calculates each partner's load transferring amount according to Handover Weight and load ratio. The relative handover parameters are adjusted. Therefore, the proposed handover policy can achieve tradeoff between the handover performance and signaling costs as well as handover failure to improve system performance and user experience.

IV. SIMULATION ANALYSIS

A. Simulation Platform Configuration

In order to test the performance of proposed self-organizing load balancing framework, especially SCPC and CLBPS, a FRS based two-hop cellular OFDMA system-level simulation platform is established. It contains 9 cells with 54 Relay Stations. Users are randomly non-uniform distributed. The detailed simulation parameters are listed in Table 3, typical values are used as in [16].

Table 3 Simulation parameter

Parameter	Value
Total Number of Sub-channels	306
OFDM subcarrier bandwidth	10.9375KHZ
Carrier Frequency	2GHz
Total bandwidth	20MHz
Cell Radius	1km
Distance between BS and RS	2/3 Cell Radius
Antenna	Omni-directional(BS,RS)
BS Tx. power	46dBm
RS Tx. power	37dBm
Initial sub-channel of BS	126
Initial sub-channel of RS	24 (Each RS), 144(Total 6 RS)
Initial sub-channel of reservation	36
Path Loss Model	40 *lg* (*r*) + 30 *lg* (*f*) + 49, r-km
Fading Model	Lognormal fading

In the initial simulator, the Comprehensive Load Balancing Policy Stack (CLBPS) utilizes two load balancing policies: Resource Reservation (RR) and Channel Borrowing (CB), as described in Section 3. In order to test proposed CLBPS in FRS based cellular network, three schemes: FRS network without load balancing scheme, standalone SON resource reservation scheme (also refer to section 3), CLBPS sequential resource reservation and channel borrowing scheme, are compared in this section.

B. Simulation Results

Figure 4 compares the new call blocking of three schemes, which is a vital importance indicator of user experience and network performance.

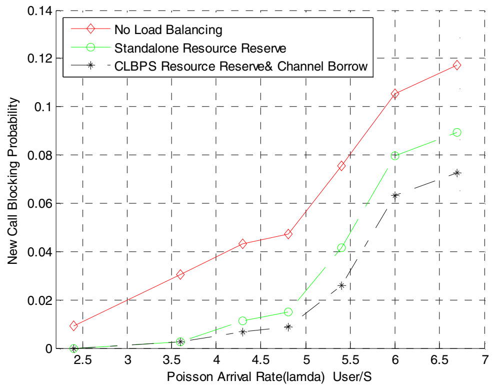

Fig.4 Call blocking probability VS arrival rate

It has shown that new call has more chances to get access to the network with CLBPS sequential resource reservation and channel borrowing scheme. Compared with standalone SON RR policy, CLBPS sequential LB scheme has significant performance improvement especially high arrival rate. This is because both BS and RS utilize the reserved resource flexibly, and load balancing partners can be updated dynamically, and then borrowing appropriate resources from SCPC according to network conditions, and therefore load balancing objective is achieved without aggregating load status of partners.

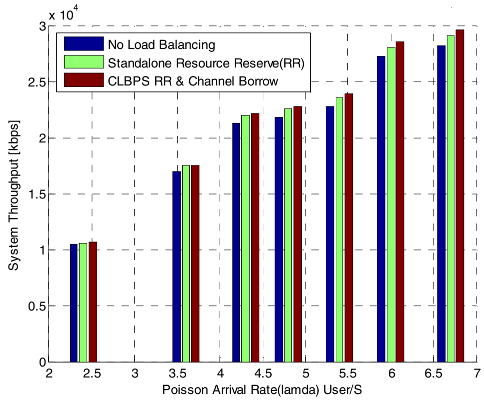

Fig.5 FRS network throughput comparison

Figure 5 shows that CLBPS have a slightly higher network throughput compared with the other two schemes and the throughput increment is more obvious with the higher user arrival rate. Basically it shows that CLBPS brings more gain to networks with relative higher load than light loaded ones. This is because the CLBPS effectively makes use of spectrum available to deal with unequal load, assisting users to get access to network easily, which in turn, increases the system throughput.

V. CONCLUSIONS

A novel self-organizing load balancing framework is proposed. The framework focuses on the novel Self-organizing Cooperative Partner Cluster (SCPC) and Comprehensive Load Balancing Policy Stack (CLBPS). Compared with the existing SON load balancing, this framework investigates the FRS networks with novel signaling costs and user experience factors. In addition, according to network environment, CLBPS makes use of single LB policy or combine multiple policies into joint LB policies to utilize the merits of various policies, rather than traditional standalone and fixed LB policy. The simulations has shown the new call have more chances to get access to the network with the proposed CLBPS sequential resource reservation and channel borrowing scheme in comparison with the standalone resource reserve scheme. CLBPS can also achieve a slightly higher network throughput in the higher user arrival rate.

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