Pricing Strategies in Multi-Operator Heterogeneous Wireless Networks

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Abstract— **In this paper, three pricing scenarios are proposed to set the transaction cost of the inter-operators agreement in a multi-operator cooperative environment. An analysis, of the operators' profits, is performed for these cooperation scenarios and different price sharing models are investigated for comparison. First, we describe the proposed pricing scenarios, the motivation behind and the points of evaluation for each scenario. Then, we present the hybrid decision algorithm for the selection of the access in a multi-operator wireless networks environment. Next, we present two business models made for the simulation, in order to highlight how network conditions and operator's strategy for service price may affect the profitability of the cooperation. Simulation results show that proposed pricing models guarantee profit gain for the cooperating operators, and are suitable in a multi-operator sharing environment. A best pricing scenario can be decided depending on the deployed capacity for sharing and the user's service price settings.**

Keywords— ***Multi-operator sharing networks; cooperation; access selection; service pricing; transaction cost, cooperation awareness.***

I. INTRODUCTION

The mobile broadband traffic is growing in a rapid manner, facing network operators with the challenge of expanding capacity and enhancing the Quality of Service (QoS) of their communication networks. In addition, operators are worried about the decrease of revenues especially from voice services, and they sense the need of new technical and network solutions that can generate new sources of revenues. Business solutions introduced in [1] show that mobile operators cooperate with other competitors and customers; some proposed partners can be providers of a non-telecom service like financial institutes, public transportation or third parties taking intermediary roles. Multi-operators cooperation in the form of open access and always best connected, has been proposed in a number of large research projects like Ambient Networks [2], SPICE [3]… etc. and several types of cooperation between networks and business entities are made. The cooperation of wireless network operators in a sharing environment is also introduced in [3] as a cost effective network solution to expand capacity and improve operators' profitability. Indeed, many works has showed that in a heterogeneous wireless environment, operators' cooperation is unavoidable and inter-operator agreements can bring benefits in terms of both network performance and operators' revenues [5][6]. In addition, new mobile architecture arises in order to help operator upgrading their access networks, and enable network sharing in a Cloud Radio Access Network [7].

In our work, we consider a cooperative environment where wireless network operators share their access resources, to upgrade their networks' capacity and improve performance in terms of clients' rejection and QoS degradation. In such cooperative environment, when an operator is unable to satisfy his client, he gives him access to the service through another network operator, thus avoiding his rejection. Consequently, a selection decision is needed when more than one operator are available for cooperation. In addition, a transaction cost is to be set in order to guarantee QoS and achieve additional revenues thus, making cooperation more profitable.

In the context of multiple operators, most of the recent works study the selection of access and service pricing using game theory as in [9][10]. In a previous work, we proposed a cost function for the selection decision in a multi-operators environment, and we showed the efficiency of our algorithm in [11] and how the operator can control the selection decision in [12].

In this paper, three new pricing scenarios are proposed as flat price scenarios for the inter-operator transaction cost. We perform a thorough analysis of these pricing scenarios and a comparison with price sharing scenarios. Moreover, the proposed scenarios for a flat transaction cost price presented better profitability comparing to price sharing models, in some operator cases of deployed capacity and service price settings.

The rest of the paper is organized as follows: Section II presents relevant existing work related to business models in a multi-operator environment. Section III describes the proposed pricing scenarios for the transaction cost in a sharing environment, and the decision algorithm used for selection is presented in section IV. The simulated business models are depicted in section V. Section VI shows the simulation results for the efficiency of the selection algorithm, and elaborates the results for the pricing scenarios profitability, in each business model. Finally, in section VII, a conclusion is made for the best pricing scenario in function of capacity and service price settings.

II. BACKGROUNG AND RELATED WORKS

Mobile operator cooperation is introduced in [1] as a networking solution to reduce networks cost and generates new type of revenues. The author focuses on cost saving

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strategies based on cooperation through network sharing, spectrum sharing and roaming, besides femtocell deployment. Investigations on the drivers of cooperation revealed that from cost perspective the incentive to share networks might be lower today since a large number of base station sites can be re-used and since the price of radio equipments has been reduced. But, entering to the mobile market and keeping a position in this market motivate mobile competitors to cooperate [13].

When cooperation decision is made, the sharing partners have to agree on several aspects such as: how much of the network should be shared, how to share costs for investment and use of the network, how to make decision for network expansion, etc. Thus, a sharing agreement must be settled between different competitors in order to manage radio resources in such multi-operator, multi-access, wireless networks. In [14], authors describe the business models for shared networks, based on fragmented wireless access and service market. Two examples are presented, the first includes Mobile Network Operators (MNOs) that offer wide area wireless access to specialized service providers, and the second includes Local Service and Access Providers (LSAPs), interacting with service providers and mobile operators via Inter-Connection Provider (ICP). In such a fragmented market, an LSAP may also provide services via other LSAPs or MNOs networks, and MNOs can also lease capacity from LSAPS, thus a cooperative environment can be envisaged. Moreover, authors propose that network selection is performed by either the service provider or an ICP to preserve competition and reduce transaction costs. This ICP will also maintain the Service Level Agreement between radio access providers and service providers. The concept of a third trusty party is adopted also in [5] for inter-operators joint resource management. Inter-operators agreements for network selection decision and users' transaction cost are maintained and guaranteed by a meta-operator acting as a trading agent between cooperating operators.

Authors propose in [5] a two-layer JRRM (Joint Radio Resource Management) strategy based on fuzzy neural methodology. Its objective is to provide the most appropriate RAT (Radio Access Technology). Then, authors assumed that the total revenue generated by the user p is shared between the two involved operators. This enables the service operator to get αp where $0 \leq \alpha \leq 1$. The first model consists of an inter-operator agreement where the service operator gets all revenue with $\alpha=1$, this model is more beneficial for the operator that correctly estimates the infrastructure deployment. The second model consists to share revenue in function of the normalized load η of the service operator with $\alpha=\eta$, this model is fair for the service operator. A second work of the authors [6] proposes an additional revenue sharing model based on the service quality experienced by the users in terms of churning rate of the home operator which is a function of its blocking probability P_b, thus setting $\alpha=C(P_b)$ the user's churning rate. Performance evaluation showed that this novel sharing model keeps a fairer behavior of both previously proposed business models.

In this paper, we propose three new pricing models for the inter-operator transaction cost. The transaction of a user consists of transferring this user from his home operator (H-op) which has contract with, to a new service operator (S-op). The latter sets the transaction cost *Cs* and the H-op will pay it. The global achieved profits are compared using these new models and the price sharing models, in order to conclude the best pricing scenario for an operator qualified as the cheapest operator or having the best capacity deployment.

III. TRANSACTION COST PRICING

The inter-operator financial agreement should determine how the user transaction cost *Cs* is set between cooperating operators. In this paper, we test the profitability of three new pricing scenarios, where S-op$_i$ sets Cs_i, by three different functions of the service price p_i as described in the following (p_i is the price paid by the client of the operator *i*).

A. Scenario S1:

To prevent any loss of investment, a guest user (user coming from another operator) must generate the same revenue as from a client user. Thus, the transaction cost of a S-op$_i$ is set equal to the service price, thus $Cs_i=p_i$. In this scenario, we intend to assess the following points:

1. *Profits improvement especially for operators with cheap service price sp.*
2. *Benefit from cooperation of an operator with the most expensive service cost.*
3. *Effect on the client acceptance especially for operators with the cheapest sp.*

B. Scenario S2:

We may notice, in *S1*, that an operator having the cheapest service price will pay a high price for its client transfer and gain less from guest users. It could face losses when client transaction is frequent. Thus, in this scenario, we propose that $Cs=max_i(sp_i) \quad i=1,2,3\ldots$ In this scenario, it is guaranteed that all available S-op offers set the same cost for H-op. Hence, we intend to test if:

1. *The cooperation still beneficial for operators even when it causes profit losses.*
2. *The operator having the cheapest price is improving his profits.*

C. Scenario S3:

To improve users' acceptance, an operator may perform a high rate of user's transaction, which causes a lot of charges in S2. Operators may find better to pay less and get less than pay more. Thus, S3 proposes a price $Cs=min_i(sp_i) \quad i=1,2,3\ldots$ The study of this scenario targets *the possibility of achieving profit gain with a low service cost.*

D. Scenario pShare:

With price sharing S-op takes a share from the user payment αp thus, H-op keeps $(1-\alpha)p$, where $\alpha \geq 0$. Depending on the value of α, different sub-scenarios can be envisaged:

1) *Scenario pShare1:* In this model, *α=1*, i.e, S-op gets all the revenue from user transfer.

2) *Scenario pShare0:* In this model, *α*=0, i.e, no charges are depicted for user exchange, and H-op gets all client's payment.

3) *Scenario pShare-:* In this model, *α<1*, i.e, additional revenues are guaranted for both H-p and S-op. Without loss of generality we show the results for α=0.25 and 0.6.

IV. OPERATOR SELECTION DECISION

In our previous work [11], we proposed a cost function *CF* that enables to select the operator having a score S_T at minimum distance of the user score *Su*, while maximizing the home operator transaction profit *(p-Cs).* Simple Additive Weighting SAW is used to calculate *Su* which combines the QoS requirements of the user application, and S_T which combines corresponding QoS parameters delivered by the S-op. Thus, the selected *S-opi* is the operator having the lowest *CF*, with:

$$CF_i=W_u*|Su-S_{Ti}|-W_{op}*(p-Cs_i) \quad (1)$$

Where, *Wu* and *Wop* are weighting coefficients that determine the degree of importance for the user satisfaction compared to profit satisfaction, respectively. Details concerning the cost function *CF* are provided in our previous work [11].

V. SIMULATED SYSTEM MODELS

For the simulations, we consider two business models *MI,* and *MII.*

A. MI-Capacity effect

In model MI, we assume that all operators deliver the same QoS specifications for the mobile users and set the same service price $sp_1= sp_2= sp_3$, then we consider different capacity for each operator. Setting the same service price for all operators reduces the simulations to *S1* and *pShare* scenarios.

B. MII-Service Price effect

In model MII, we assume that all operators deliver the same QoS specifications, have the same capacity, but set different service prices *sp.*

These business models are made for simulation, in order to reveal which pricing scenario is more profitable in function of the shared capacity and the service price.

VI. SIMULATION RESULTS

A. Simulation Setup

We consider three cooperating operators; Op_1, Op_2 and Op_3 as in Fig.1, The delivered parameters and the service prices for each operator are depicted in Table I, for each model MI and MII.

Users arrive to the system sequentially and we model the arrival and departure of users as a Poisson Process with mean arrival interval 1/λ seconds. We perform simulation for different values taken from 1/λ= [6 4.8 4 3.43 3 2.67]. Once connected, the user will stay in the system for a service time assumed to follow an exponential distribution of mean 1/μ=4 min. The simulations are implemented in Matlab for duration of 1200 seconds each and repeated for 30 experiments.

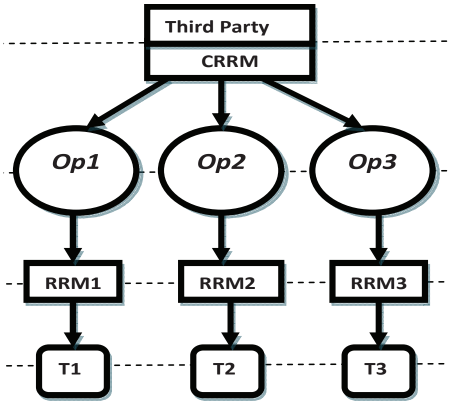

Fig. 1.Multi-operator system model

TABLE I. OPERATORS' NETWORK PARAMETERS

System model	**Operators' Network Settings**		
	Capacity(Kb/s) [Op_1,Op_2,Op_3]	***Service Price(units/Kbytes)***	***QoS specifications [J_M, D_M,BER_M]***
MI	[11000, 9000, 5000]	*sp=0.5*	[10, 30, 10^{-5}]
MII	11000	sp_1=0.3, sp_2=0.5 and sp_3=0.9	[10, 30, 10^{-5}]

B. Selection Algorithm efficiency

The efficiency of the selection algorithm is shown through the blocking rate improvement for each operator of the system (*Op1*, *Op2*, and *Op3)*, and the profits achieved via cooperation. The comparison of performance in terms of blocking rate and profits is done for the scenarios *S1, S2, S3* and the case where there are no inter-operator agreements for cooperation.

1) Blocking rates improvement

Figures 2a, 2b and 2c show how the cooperation between *Op1*, *Op2*, *and Op3,* respectively, could reduce the blocking rates especially for high number of system arrivals. The maximum number of admitted users for each operator is increased of more than 20%, inducing an increase of the user acceptance in the whole system up to 24% for a blocking probability of 2%. This translates the capacity gain achieved through cooperation. Note that this improvement is the same for the three inter-operator agreements *S1, S2 and S3.*

2) Profits Improvement

Figures 3a, 3b and 3c show the total profits achieved by *Op1, Op2* and *Op3,* respectively. Operators could gain more revenues through cooperation; the user acceptance is improved and extra revenues are gained from guest users. The proposed pricing scenarios guaranteed higher profits for all cooperating operators. In addition, Fig. 3c shows that *S1* is the

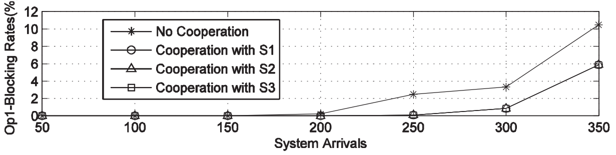

Fig. 2a. Op1's blocking rates improvement

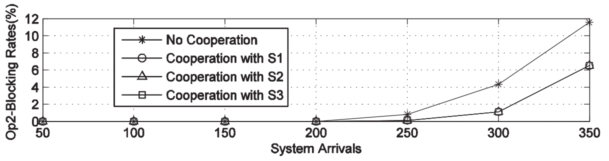

Fig. 2b. Op2's blocking rates improvement

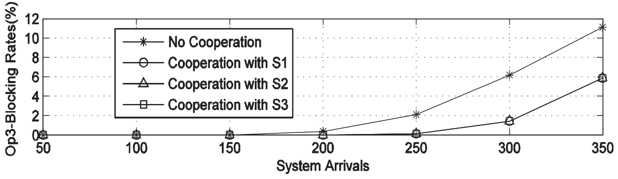

Fig. 2c. Op3's blocking rates improvement

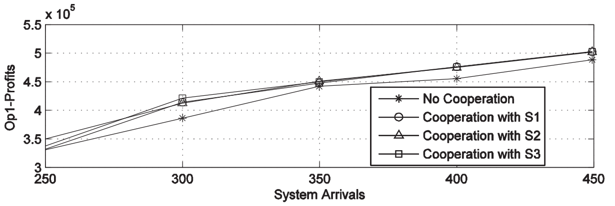

Fig. 3a. Op1's profit improvement

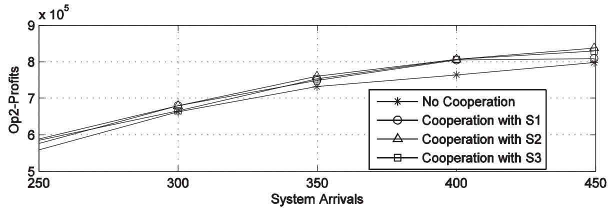

Fig. 3b. Op2's profit improvement

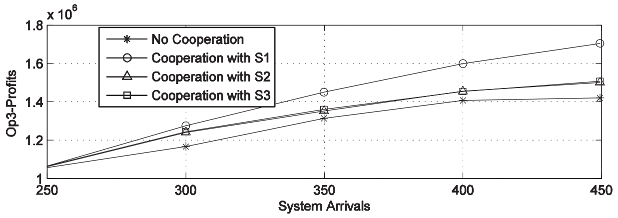

Fig. 3c. Op3's profit improvement

best pricing scenario to adopt by *Op3*, which sets a high service price *p*.

C. *Pricing Scenarios Comparison*

1) *Capacity based Comparison-Model MI:*

In model MI, operators differ in the deployed capacity for sharing Table I. Figures 4a, 4b and 4c show the profit achievements for *Op1, Op2* and *Op3*, respectively, with each pricing scenario in addition to the case where no inter-operator agreement is made (No cooperation scenario).

First, note that *S1, S2* and *S3* produce the same profits as the *pShare1* scenario, for all operators ($p_1=p_2=p_3$). The proposed scenarios guarantee high profits for the operator deploying a high capacity. But, these scenarios do not improve the achieved profits for *Op3,* having the lowest capacity, and losses may occur at same number of system arrivals. The proposed pricing scenario *S1,* retaining the same price for clients and cooperating operators $Cs_i=p_i$, guarantees the highest transaction cost (0.5 *units/Kbytes*) for the S-op compared to the *pShare* scenarios (with α<1). Thus, as much the cooperating operator can serve guest users as much it gets profits. However, when the operator wants to improve its user acceptance with a lot of client transfer to another S-op, high charges have to be paid. In addition, with the *pShare0* scenario, where the H-op keeps all its client payment and S-op loses additional revenues from guest user. This scenario

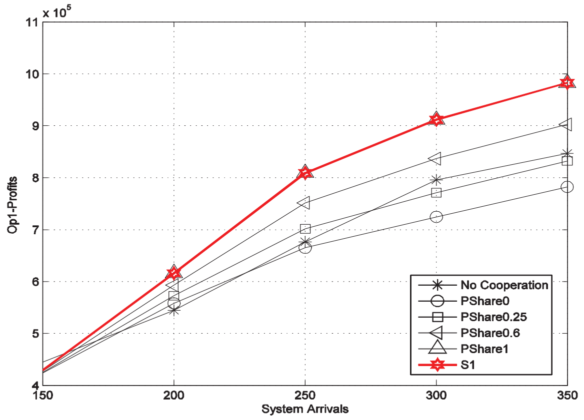

Fig. 4a. Op1's achieved profit (with high capacity)

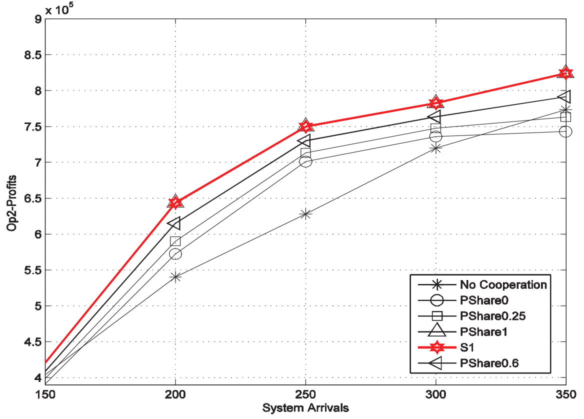

Fig. 4b. Op2's achieved profit (with moderate capacity)

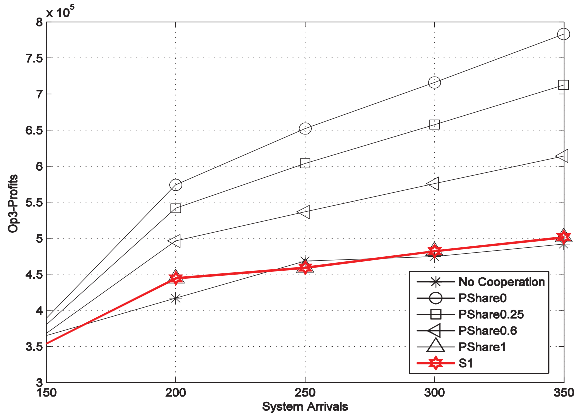

Fig. 4c. Op3's achieved profit (with low capacity)

causes a lot of losses for *Op1,* at high system arrivals. In fact, at these rates, *Op1* is serving a high number of guest users, without additional revenues that may recover charges or probable client payments. Thus, our proposed pricing scenarios guarantee the best profits for the operators having a good dimensioning for sharing.

2) Service price based Comparison-Model MII:

In model MII, operators differ in the service prices ($sp_1<sp_2<sp_3$). We are interested to show the profit improvement for *Op1* and *Op3* setting the cheapest and the most expensive service price *p*, respectively.

Figure 5a and 5b show the profits achieved by *Op1* and *Op3*, respectively, with the different pricing scenarios. Results show that with the proposed pricing scenarios *S1, S2* and *S3*, *Op3* could maximize its profits especially for high system arrivals, where other price sharing scenarios cause losses. In fact, *Op3* could achieve the highest profits with *S1*. For *Op1, S2* and *S3* could improve its profits via cooperation but not as much price sharing scenarios did. Scenario *S1* causes losses for *Op1,* at high system arrivals, where this operator transfers its clients to more expensive operators, and served guests do not assure enough revenues to recover transaction cost. Hence, *S1* is to be avoided by the operator setting the lowest service price.

VII. CONCLUSION

In this paper, three pricing scenarios are proposed for the transaction cost of the inter-operator agreement, in order to improve operators' revenues through cooperation, in a multi-operator environment. These scenarios are analyzed and compared together and with different price sharing scenarios.

Simulation results, using our modified cost function for access selection decision, have shown that the establishment of inter-operator agreements brings benefits in terms of user acceptance and operators' profits. The proposed scenario *S1,* that maintain the same price for clients and cooperating operators has been shown as the best financial agreement for the operators having a good dimensioning for shared capacity, and the operator setting the higher service price in the cooperating system. When *S1* caused losses for the operator setting the lowest service price in the system, other scenarios *S2* and *S3* could improve profits and make cooperation profitable. Future work will take advantage of game theory as a tool for operator selection and inter-operator service pricing.

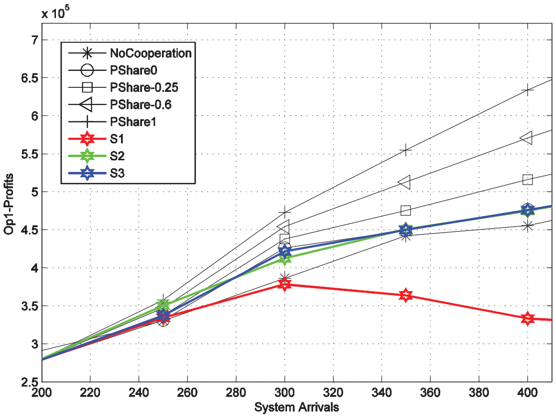

Fig. 5a. MII-Op1's achieved profits

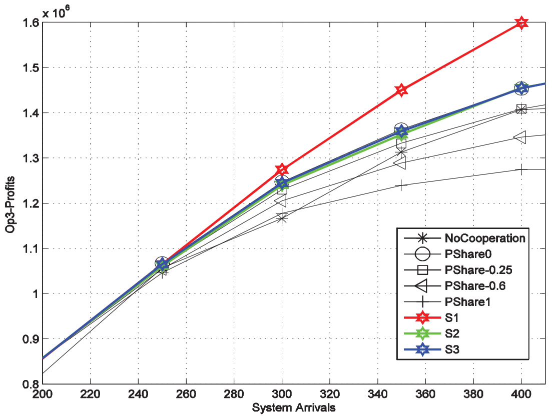

Fig. 5b. MII-Op3's achieved profits

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