International Roaming Traffic Optimization with Call Quality

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Abstract: In this study we focus on a Steering International Roaming Traffic (SIRT) problem with single service that concerns a telecommunication's operators' agreements with other operators in order to enable subscribers access services, without interruption, when they are out of operators' coverage area. In these agreements, a subscriber's call from abroad is steered to partner operator. The decision for which each call will be forwarded to the partner is based on the user's location (country/city), price of the partner operator for that location and the service quality of partner operator. We develop an optimization model that considers agreement constraints and quality requirements while satisfying subscribers demand over a predetermined time interval. We test the performance of the proposed approach using different execution policies such as running the model once and fixing the roaming decisions over the planning interval or dynamically updating the decisions using a rolling horizon approach. We present a rigorous trade off analysis that aims to help the decision maker in assessing the relative importance of cost, quality and ease of implementation. Our results show that steering cost is decreased by approximately 25% and operator mistakes are avoided with the developed optimization model while the quality of the steered calls is kept above the base quality level.

1 INTRODUCTION

Competition in the telecommunication sector has increased in the last years since the number of operators has increased. The high number of partner operators who can make steering for each location decreased the price of traffic movement, yet the profit margins of operators are also decreased. For operators wishing to survive in this competitive environment, keeping the international traffic steering costs to a minimum by making the right cross connection agreements has become more important and complex than ever.

Operators need to update their steering decisions instantly because of instant changes on market situations in order to minimize their traffic steering costs and increasing their profits. Currently traffic steering decisions are made manually. These decisions cannot converge to optimality, because, steering costs may differ day to day and the size of data is very large. These situations makes decision makers prone to mistakes.

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Literature in telecommunication sector is mostly available on specific optimization models for communication network design (Pióro and Medhi, 2004). Although some works about designing and optimizing telecommunication networks according to demand are widely available in literature (Flippo et al., 2000), (Gendreau et al., 2006), (Riis and Andersen, 2004), an optimization model for service management is not available except the two latest works.

In the first one (Martins et al., 2017), some mixed-integer linear formulations are presented for the problem named Steering International Roaming Traffic (SIRT) with different agreement methods. Their objective is to decide the quantity of voice traffic that will be steered to optimize the wholesales margin that occurs when steering some voice traffic to different operators from different countries.

In the second one (Esteves et al., 2018), a mixed-integer linear formulation is presented for the multi-service SIRT problem which is specified as an NP-hard problem. The designed model aims to minimize the sum of the wholesale roaming costs associated to the commercial agreements between Orange Telecommunications Group (OTG) and its partner operators in 43 countries of Europe and North America.

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The model is run for 5 simulated instances based on the yearly forecasts of the amount of roaming traffics of OTG subscribers in each visited country and the problem is solved simultaneously for data and voice traffics with different agreement types. The optimal results are found within 5 minutes for 4 of 5 instances and the remaining one is concluded with an optimality gap of 0.21%. The results are compared with a scenario which assumes that the whole roaming traffic is distributed equally and randomly to the partner operators in the respective countries. According to the comparison, their model provides an average of 30% improvement in wholesale roaming costs of OTG.

However the call quality is not considered in these proposed models. According to (Lacasa, 2011), in a market where traffic steerings are perfectly performed, no operator has market power and the competitive advantage is always in the side of lower prices. For this reason, quality is a necessity rather than being an important criterion for operators who are advantageous in terms of their market positions to maintain these advantages. In this paper, we propose a new steering model for single service (only voice steering) with call quality and apply by using a real-life dataset of call steering transaction provide by Turkcell which is the market leader company in Turkish GSM sector. The optimal steering decisions are found, steering cost is decreased by approximately 25% and operator mistakes are avoided with the developed optimization model. In addition, the quality of the steered calls is kept above a certain threshold.

The rest of the paper is organized as follows: We describe the problem and introduce data in Section 2. We describe steering model with call quality in Section 3. In Section 4, we present results and conclude in Section 5.

2 PROBLEM DESCRIPTION

When looking at the roaming services in the telecommunications sector, we can categorize the roaming services provided by operators into two different markets: retail markets where operators sell roaming services to their own customers, and wholesale markets where operators allow the customers of other operators (partner operators) in other countries to connect to their network when abroad (Salsas and Koboldt, 2004). Telecommunication operators interconnect with other operators when it is not possible to complete an end–to–end call entirely on a single operator's network (Figure 1). In such situations, traffic is steered to partner operators to satisfy customer demand. This steering operation may occur in various scenarios. A call may originate within operator A's network and terminate on operator B's network. In a more complicated scenario, a call originates on operator A's network, transits through operator B's network, and then terminates on operator C's network. In that case, operator A must interconnect with operator B and operator B must interconnect with operator C. These new routing options force operators to establish and manage multiple interconnect agreements in order to optimize the use of their networks, reduce costs, and increase margins.

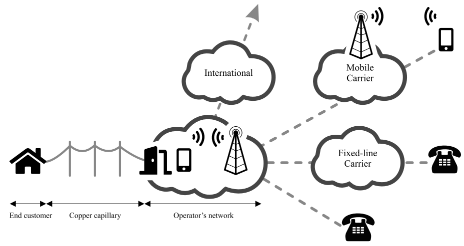

Figure 1: Network diagram of home operator.

The problem we solve in this paper is to steer the international voice traffic of the home operator, Turkcell, with minimum cost and keep the quality on acceptable level. International call steering consists of two part: 1) outgoing traffic steering, 2) incoming traffic steering.

Outgoing traffic is the steered volume to partner operators on daily basis. There are some commitment agreements between home operator and partner operators for traffic steering. These agreements may not lead to any profit at current period but they may increase the business volume, price discounts and commercial trust in the future period. In addition to these, these agreements are important because of the quality factor of the traffic steering which has an affect on customer satisfaction. So, besides the cost of steering, keeping the quality on an acceptable level is also important for outgoing steering decisions.

On the other hand, incoming traffic is the steered volume sent to home operator from partner operators on daily basis. Incoming traffic is priced by home operator, however it cannot interfere with the routing processes except for the pricing; it is only obliged to carry the demand to desired target within the scope of the commitments made between two operators.

2.1 Dataset

In this part, data acquisition for the inputs of the model and the properties of data are described. Objective of the model is to keep quality level on particular level while decreasing the traffic steering cost. In order to create the model these data types are used:

- Unit price per minute based on location by operators (Tariff)
- Locations where operators provide service
- Outgoing demand information
- Details of agreements with other operators
- Call Detail Record (to determine quality metric)

This dataset is provided by Turkcell. Turkcell is the market leader in Turkish GSM market with 44% market share and the annual income of US$4.4B in 2018 (Turkcell, 2018). In addition to the 33.8 million customers in Turkish market, Turkcell is a global company and it serves 12.2 million customers in Azerbaijan, Kazakhstan, Georgia, Moldova, Northern Cyprus and Ukraine. Turkcell has international roaming agreements with 622 operators in 201 countries as of 2018.

The data is available for international traffic between 1.7.2017-31.10.2017 in worldwide. In the incoming traffic data, there are 111 operators and 555 prefixes which belong to the operators. For outgoing traffic, there are 109 operators ant 573 prefixes in the data. Also, the information about agreements of 7 operator and 86 locations is available in the data.

2.2 Agreements

With the increasing international roaming traffic, competition in the wholesale roaming services among operators has gained a different dimension. In order to provide better commercial conditions in this competitive environment, the operators developed trade agreements named International Roaming Agreement (IRA). Under these agreements, unit prices named International Operator Tariffs (IOT's) are determined unilaterally by the home operators. Lower unit prices can be defined for higher volume traffic with bilateral agreements. These agreements are based on mutual commitments.

There are four basic IRA's used in wholesale roaming market. The first one is the pricing method called Quantity (QNT) or Degressive / Progressive Charging that uses a piece-wise function. According to this model, pricing is made within predetermined proportional thresholds and it is done with X unit price up to the limit of a certain steering volume, and when the limit is exceeded pricing is made with a lower Y unit price than X for all traffic from the beginning (Figure 2a).

The second model is the pricing model called Incremental (INC) or Tiered Charging, where prices are calculated in a cumulative manner with predetermined volume intervals (segments) and unit prices for these intervals (segment prices). In this model, similar to QNT, thresholds and segment prices are determined but differently when the segment of unit price Y is exceeded, the price of the steered traffic in the segment of unit price X is calculated over the X unit price so the total price is incrementally calculated based on the volume steered in respective segments (Figure 2b).

A third model, called Balanced/Unbalanced (BUB), is a pricing model where the amount of bilaterally routing is fixed, and the exceeding part of the traffic is priced at a reduced price. For example, if we consider that an operator A steers 1000 minutes to the operator B and B steers 2000 minutes to the A; operator A pays the price of 1000 minutes volume at the unit price of B, whereas the operator B pays the price of 1000 minutes at the unit price of A plus the price of exceeding 1000 minutes at the reduced price of A (Figure 2c).

The fourth model is the pricing model, named Send-Or-Pay (SOP), where the pricing of a predetermined volume is committed and paid regardless of the amount of steering, and after the committed limit is exceeded, pricing has to be done with one of the other pricing models (ie. QNT, INC or BUB) for the exceeding amount. For instance, when operator A makes a 1000-minutes commitment and if they only steer 800-minutes voice traffic, they pay the contract amount which is the price of maximum 1000-minutes steering. After 1000 minutes, one of the other agreed pricing models comes into play (Figure 2d).

As Turkcell is one of the rule-setting operators in its own market region, they use a unique pricing method similar to the BUB model, but unlikely to the BUB, commitments are made and the exceeding volume is paid by negotiating according to the fulfillment rates of the both parties. In this method, since the cost calculation can only be made depending on the strategical decisions of the administrative committee, in the cases where the commitments cannot be fulfilled; the objective should be designated to minimize the steering costs while setting up the mathematical model. Thus, Turkcell takes the advantage in the negotiation phase.

There are two different partner operator types in the problem. They are committed operators (CO) and uncommitted operators (UO). UO are priced on minutely based tariff and there is no guarantee on volume of service. The main reason of the agreements is to have better price on predetermined volume of calling minutes.

CO typically specify how they will exchange termination services. The party that sends more traffic compensates the other party based on the amount of

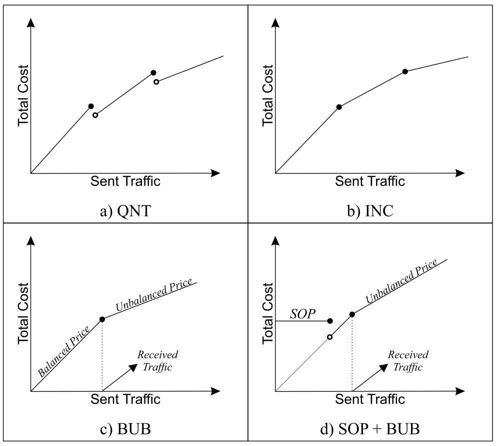

Figure 2: Payment models (Esteves et al., 2018).

traffic surplus. In this case, inter–network traffic measurements are required for settlement purposes.

Agreement details with CO are:

- Agreements are between home operator and CO's.
- All agreements are only valid for limited time.
- Agreements with CO's may be valid at more than one location.
- Information of valid locations and incoming/outgoing call traffic volume are clearly stated on agreement. So, agreements can include both way of traffic (From home operator to CO and from CO to home operators).
- Different currencies can be used on agreements.
- To reach the call traffic volume or getting closer to limit is the main principle. In another saying there is no penalty for not exceeding the limit. Even if there is no penalty, it is essential to get closer to the limit for business agreements at the end of term. This situation creates trust issues between operators and it leads decrements on business volume. Also, by fulfilling the agreed volume may bring some price advantages on next agreements' prices.

The example of agreement with a CO is shown in Table 1.

2.3 Outgoing Demand

Call Detail Record (CDR) is a detailed dataset containing the time of call, length, competition status, source phone number and destination phone number. Outgoing demands are extracted from CDR and Figure 3 shows the demand of the calls on one-month period. Also, Figure 4 shows the demand of data roaming for the same interval. It is seen that on calls and data roaming shows periodic behaviors on weekends.

Table 1: Example of agreements with CO.

Committed operator		Currency	
X		EUR	
Start Date		End Date	
1.07.2017		31.12.2017	
Outgoing Traffic		Incoming Traffic	
Location	Volume	Location	Volume
D1	8,500,000	D5	20,000,000
D2	1,000,000	D6	7,500,000
D3	2,250,000	D7	10,000,000
D4	1,500,000		

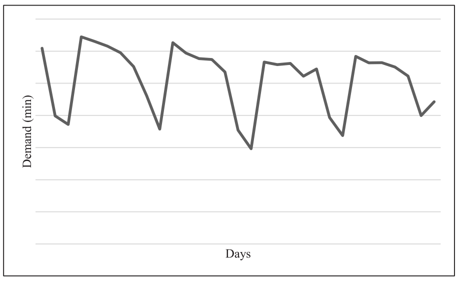

Figure 3: Demand Voice.

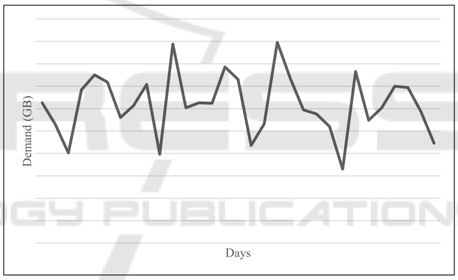

Figure 4: Demand Data.

2.4 Analysis of Quality Metrics

Answer seizure ratio, network efficiency ratio, average call duration, and post dial delay are calculated by using CDR data. These parameters are recommended by International Telecommunication Union as performance metrics of network (ITU-T, 2002).

- Answer Seizure Ratio (ASR) is a measure of the network quality which is calculated by the percentage of the number of successfully connected calls to the number of attempted calls (it is also called the call completion rate).

$$ASR = \frac{\text{Seizures resulting in answer signal}}{\text{Total seizures}} \quad (1)$$

- Network Efficiency Ratio (NER) measures capability of network to call terminal. Rather than the ASR, NER excludes the customer and terminal behaviors. So, it represents the pure network performance better.

$$NER = \frac{\text{Seizures resulting in Answer message or User Failure}}{\text{Total seizures}} \qquad (2)$$

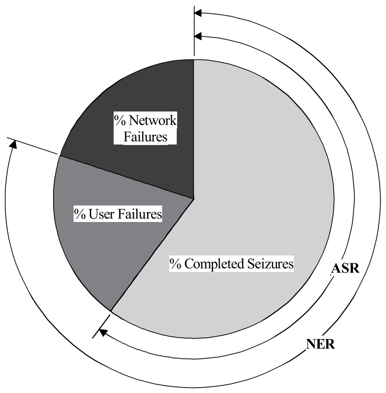

Figure 5: ASR and NER comparison (ITU-T, 2002).

- Average Call Duration (ACD) is calculated by using call count and total call duration. In general assumption, there is a positive linear relationship between ACD and the call quality.
- Post Dial Delay (PDD) is the time it takes to receive feedback after a user has finished dialing (after they pressed the dial button on their phone). PDD is used to predict the length of the way to destination from call source. Lower PDD means better user experience.

Table 2 represents the correlation among quality metrics and correlation with respect to unit prices. It is seen that there is no direct relation between unit price and quality metrics.

Table 2: Correlation Matrix of Quality Metrics and Unit Prices.

	ASR	NER	ACD	PDD	Price
ASR		0.72	-0.23	-0.02	0.09
NER	0.72		-0.21	0.01	0.11
ACD	-0.23	-0.21		0.26	0.15
PDD	-0.02	0.01	0.26		0.13
Price	0.09	0.11	0.15	0.13	

ACD is not a reliable performance metric, because customers tend to terminate the call in a short period in long distance call due to extra costs. On the other hand, PDD can be affected by many external factors other than general network quality. This situation makes PDD unusable for our model. ASR and NER are both good metrics to evaluate general performance and they are correlated as seen in Figure 6. However, ASR takes only completed seizures into account while NER also considers user failures (Figure 5). Since, NER is more comprehensive, it sets a better threshold for measuring network quality.

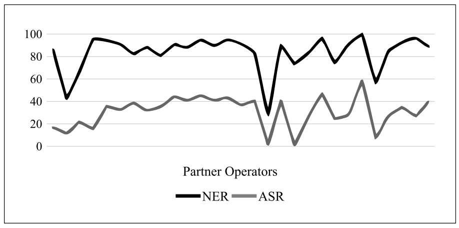

Figure 6: Average ASR and NER comparison of some operators.

Figure 7 represents the past quality of two partner operators with the highest amount of steering(Operator_1094, Operator_23) and two partner operators with the least amount of steering (Operator_796, Operator_27) according to average quality values of the historical data.

As seen in continuous quality values in Figure 7, the variances of the quality values are in narrow ranges, which endorses our previous assumption of using average quality values. In our model, quality calculation for decided steering values which has no past data for the relevant prefixes, is done by using the average quality of the operators' average quality in that location. If there is no quality information about any prefixes in a location, then the general average quality of the operator in all locations is used.

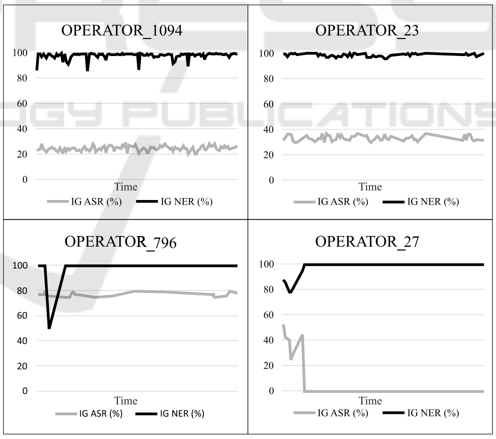

Figure 7: Quality comparison of some operators.

3 STEERING MODEL WITH CALL QUALITY

After data analysis and processing, a mathematical model for steering of international roaming is proposed with cost minimization objective. The model determines steering decisions for international roaming traffic to each operator and each prefix while keeping the quality on acceptable level.

The notation used in the mathematical model;

sets, parameters, decision variables, and the proposed mathematical model are provided below:

Sets:

- i = operator,
- j = prefix,
- k = location,
- P_{ij} = possible operator and prefix matches,
- G_{jk} = prefix and location matches,
- A_{ik} = operator and location matches in agreements.

Parameters:

- d_j = Outgoing voice demand of prefix j,
- c_{ij} = Unit cost of outgoing voice traffic to prefix j over operator i,
- V_{ik} = Volume of agreement for location k with operator i,
- q_{ij} = Network Efficiency Ratio (NER) of operator i for prefix j,
- q_t = Quality threshold,
- M = Big Number.

Decision Variables:

- x_{ij} = amount of voice steering to prefix j over operator i,
- u^+_{ik} = amount of missing voice steering to location k over operator i,

LP Model:

$$\min \quad \sum_i \sum_j c_{ij} x_{ij} + \sum_i \sum_k M u^+_{ik} \tag{3}$$

$$s.t. \quad \sum_{i \in P_{ij}} x_{ij} = d_j \qquad \forall j \tag{4}$$

$$\sum_{i \in P_{ij}} q_{ij} x_{ij} \geq q_t \sum_{i \in P_{ij}} x_{ij} \qquad \forall j \tag{5}$$

$$\sum_{j \in G_{jk}} x_{ij} + u^+_{ik} \geq V_{ik} \qquad \forall i,k \in A_{ik} \tag{6}$$

$$x_{ij} \geq 0 \quad \forall i,j \tag{7}$$

$$u^+_{ik} \geq 0 \quad \forall i,j \tag{8}$$

The Linear Programming (LP) model presented in Equations (3) through (8) aims to minimize the total steering cost and penalizes the unsatisfied agreements' volume. In the objective function (Equation 3), Big M is a sufficiently large number that aims to firstly minimize u^+_{ik} values (set the smallest positive values possible).

Constraint 4 ensures that the outgoing demand is met for each prefix. Constraint 5 guarantee that if steering occurs to prefix j over operator i, average quality of steering have to be greater than the quality threshold. Constraint 6 ensures that satisfy the deal volume for each operator and each location. The rest of the constraints (Constraint 7 and 8) are nonnegativity constraints for variables.

We implement the model by using the GAMS IDE (GAMS Development Corporation, 2013) and CPLEX (IBM ILOG, 2010) solver for LP. We perform all experiments on an Intel Core i7-8550U 1.8GHz machine with 8GB RAM.

Next section presents the scenarios we test and discussion of the findings.

4 RESULTS

As mentioned before, the data is available for international traffic between 1.7.2017-31.10.2017 in worldwide. Certain assumptions are made for the problem. Since agreements are annual, we estimate the agreement volume (V_{ik}) for the four month period as one third of the real agreement volume.

We also make the following assumption to estimate the quality data of the operators, which do not have past quality data: if the average quality for a given prefix is missing, then the location average is used for the relevant operator. If all information about a location is missing, then general average of the operator for all locations is assumed for the average quality of any prefix for location of interest.

The optimization model is solved for voice steering. Steering costs are calculated based on the same exchange rate.

First, the model is solved with the zero quality threshold. In other words, Constraint 3 is ignored in the model (Scenario 1). The reason of this is to see the variation in the cost and average routing quality, where quality concern is completely ignored. However, the quality of routing is one of the crucial criteria of the home operator. So in Scenario 2, quality threshold is set as the historic average quality value of the home operator, aiming to see the cost reduction achieved by the model, where solution quality is matched with that of home operator's, canceling out the quality . In addition, we run a third scenario, Scenario 3, where the average quality value of the home operator is determined as a direct target and not as a lower limit, by changing inequality to equality in Constraint 3. So the model results can be comparable with the historical results. The cost of steering for all scenarios are presented in Table 3. The amount of unsatisfied commitment volume is also shown in Table 4.

In Table 3 and Table 4, the "Base" row indicates

Table 3: Total Costs and Average Quality Rates.

	Total Cost (TRY)	q_a (%)
Base	129.2M	83.80
Scenario 1	63.8M	67.93
Scenario 2	96.9M	84.20
Scenario 3	97.4M	83.80

Table 4: Sum of Unsatisfied Commitment Minutes.

	$\sum_{ik} u^+_{ik}$ (min)
Base	4,179,400.12
Scenario 1	1,261,630.10
Scenario 2	1,261,630.10
Scenario 3	1,261,630.10

the historic results of the home operator. When the quality threshold is determined as zero ($q_t = 0$) the steering costs can be reduced by half. However, when the quality threshold is equal to the historical average quality of the home operator ($q_t = 83.8\%$), the cost benefit provided by the model is around 30%. The amount of unsatisfied commitment volume is penalized with a big number, M in the model objective. For this reason, as seen in Table 4, the unsatisfied commitment volume is decreased from approximately 4.2 million minutes to 1.3 million minutes and the whole outgoing demand have been met. The unsatisfied commitment volume in the second and third scenario results is due to the low demand in the period. Naturally, the determination of the quality threshold does not cause any change.

The decision of outgoing steering in this model is made independent of the incoming traffic steered by contracted operator. However, in real life application the difference between incoming and outgoing steering, so the profit amount, affects the decision.

One of the most critical points about Turkcell's current steering policy is its trust-oriented win-win relationship with its partner operators. This relationship makes it possible for Turkcell to make some assumptions due to its market size and power in the region. One of the these assumptions of Turkcell is the assumption that when a committed amount of outgoing steering is exceeded, a same price amount of incoming steering demand will be expected. Actually this expected increase in revenue is proportional to the reliability and sustainability of the relationship between partner operators and home operator. However, in this study the correlation between incoming and outgoing steering traffic for each partner operator is specified as 1 independently from the partner operators' reliability and trade relation scores.

Therefore, the mathematical model is remodeled in such manner that it forces an increase in the volume of outgoing steering to a contracted operator which provides high incoming steering. In this way, we assume that the net profit amount always increases while the gap between incoming and outgoing traffic is closing. The current model can be run iteratively in this manner by also considering the demand gap and making an update on the unit price of an operator i for prefix j by providing a discount, and deriving an updated c_{ij} value. After the update, LP model is run again and the difference in the demand gap is observed. According to the new gap, model is run again and the process continues in the same way until the gap value converges.

The parameter w_i that is defined for this update represents the weighted profit coefficient of the operator i and it is obtained from dividing the gathered revenue minus cost for each partner operator by the total profit earned from all partner operators.

The resulting coefficient is subtracted from 1 and multiplied with parameter c_{ij} to calculate updated c_{ij} value. This new coefficient will be called a_{ij}.

$$a_{ij} = (1 - w_i)c_{ij} \qquad \forall i, j \tag{9}$$

For better understanding, let's assume that operators *ACell* and *BCell* are committed operators and *CCell* is an uncommitted operator for a home operator. The expected profit from *ACell* and *BCell* are \$60K and \$40K, respectively. In this case, the values of w_{ACell}, w_{BCell} and w_{CCell} are:

$$w_{ACell} = 60/100 = 0.6, \tag{10a}$$
$$w_{BCell} = 40/100 = 0.4, \tag{10b}$$
$$w_{CCell} = 0. \tag{10c}$$

This shows that, commitments provide 60% discount on unit price of *ACell*, and 40% discount on unit price of *BCell*. The unit price of uncommitted *CCell* remains unchanged because its expected profit is taken as zero. In this way the ones with more promissory commitments are prioritized and they become more advantageous.

Update in the unit costs showed that the models iteratively solved are converged after the third iteration and the value of total cost does not change more. The total costs, expected revenue and profit of the iterations are shown in Table 5.

Table 5: Change in Cost, Revenue and Profit in TRY.

	Cost	Revenue	Profit
Step 0	97.4M	230.4M	133.0M
Step 1	102.5M	237.1M	134.6M
Step 2	105.2M	241.4M	136.2M
Step 3	107.3M	244.3M	137.0M
Step 4	107.3M	244.3M	137.0M

According to the results, the steering decisions is changed with updated unit costs and the total cost is increased in the first and second iteration by about 4.4% and 5.3%, respectively. Under the main assumption that the increase in the costs is going to increase the revenue from committed operator with the same rate, the net profit also increases as shown in Table 5.

5 CONCLUSION

A telecommunication operator makes agreements with other operators in order to enable its own subscribers access services when the subscribers are out of the operator's coverage area. Such operators are called the partner operators and each subscriber call from abroad is steered to a partner operator. The decision for which partner the each call will be forwarded to is based on the subscribers's location (country/city), the price of the partner operator for that location and the service quality of the partner operator. Finding the best forwarding for all subscribers under the partner agreement conditions is called the Steering International Roaming Traffic (SIRT) problem.

In this study we propose to solve the SIRT problem with a single service by developing an optimization model that considers agreement constraints and quality requirements while satisfying demand from the subscribers over a predetermined time interval. We consider two executions policies to test our approach; a) running the model once and fixing the roaming decisions over the planning interval, b) dynamically updating the decisions using a rolling horizon approach. Our results show that steering cost is decreased by approximately 25% although the quality of the steered calls is kept above the base quality level.

For future work, a decision support system can be developed to monitor how to set commitment values of future agreements under different scenarios. In addition, it is possible to perform stochastic demand analysis and run the scenarios under uncertainty. Hence, the robust performance of the model can be measured.

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