Optimizing Steering of Roaming Traffic with A-number Billing Under a Rolling Horizon Policy

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Abstract. In this study, we focus on single service steering international roaming traffic (SIRT) problem by considering telecommunication operators' agreements and "a-number billing" while keeping service quality above a certain threshold. The steering decision is made considering the origin and destination of the call, total volume requirement of bilateral agreements, quality threshold and price quote of partner operators. We develop an optimization model that considers these requirements while satisfying projected demand requirements. We suggest a framework based on rolling horizon mechanism for demand forecasting and policy updating. The results show that the steering cost is decreased approximately 11% with deterministic demand and 10% with forecasted demand compared to the base cost value provided by the company. Also, the model provides approximately 26% decrease in unsatisfied committed volume in agreements.

Keywords: Steering international roaming traffic · A-number billing · Linear programming · Demand forecasting · Rolling horizon

1 Introduction

Like in many other markets, increasing number of service providers has escalated the competition in the telecommunication sector. The high number of potential partner operators, who can provide steering of roaming, decreased traffic movement charges, hence the profit margins of the operators have decreased. Making the right cross connection agreements for minimized international traffic steering costs became more crucial and complicated for the operators which are trying to survive in this competitive sector.

Due to the instantly changing market positions, steering decisions should be updated rapidly to increase profits and decrease total traffic steering cost. In most of the companies, steering decisions are given manually. Almost daily changing price quotes and excessive number of possible steering options makes it impossible to find the optimal decisions manually.

Telecommunication network design related optimization models are the frequently studied problems in the telecommunication sector related literature [13]. Studies on telecommunication network designing and optimization for demand dependent situations are very common [4,6,14], while optimization model for service management is not frequently studied.

Mixed-integer linear formulations are observed under the steering international roaming traffic (SIRT) type of problem with distinct agreement methods in [12]. The 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.

A mixed-integer linear formulation is provided for SIRT with multi-service property in [3]. Objective of the model is to minimize the sum of the wholesale roaming costs linked to the commercial agreements. These agreements are between Orange Telecommunications Groups (OTG) and operators in North America and Europe, which constitutes 43 partner operators in total. The model is run for five 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. Four out of five instances' optimal results are computed in less than five minutes. A feasible solution for the fifth problem is also found but with optimality gap of 0.21%. It is assumed that whole roaming traffic is distributed randomly and evenly to the partner operators in the corresponding countries. The provided optimization model brings 30% improvement in the OTG's wholesale roaming cost.

One important missing aspect in these studies is that none of them considers quality thresholds for steered calls. According to [11], 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 [15], SIRT problem is considered 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. An optimization model considering agreement constraints and quality requirements, while satisfying subscribers demand over a predetermined time interval is proposed.

In this paper, various extensions to [15] are proposed. First, the problem formulation along with the considered data set is extended such that more realistic scenarios will be solvable. Moreover, a demand prediction module is developed and results of the module for outgoing calls is integrated into the optimization model. More specifically, a new steering model for single service (voice steering by oneself) with quality of call with pending "a-number billing" is included under a dataset of call steering with forecasted demand belonging to a real-life case is proposed. Turkish GSM sector leader, Turkcell, has provided the dataset. Roughly 10% decrease in cost of steering is achieved by automating and optimizing steering decisions. For hte stochastic outgoing demand, a rolling horizon

approach is applied and forecasts are made for certain intervals to reflect the predicted demands into the model. For the model's output; percentage ratio are computed for each prefix, origin and carrier basis. A real test data set is used (which is hidden from the forecast model) to estimate the actual cost of steering decisions.

The rest of the paper is organized as follows: The problem is described and the data is introduced in Sect. 2. The steering model with call quality considering "a-number billing" is described in Sect. 3. Results are presented in Sect. 4 and the conclusion is provided in Sect. 5.

2   Problem Description

Operators' roaming services in telecommunication sector can be classified in two different markets, which are retail markets and wholesale markets [16]. Retail market's roaming service is for selling service to own users while wholesale market's roaming service is letting other operator's customers in different countries use network, when they are not in their origin country. Other operators are called "partner operators". If there is no chance to successfully provide end-to-end call with using single operator's network, then the operator interconnects with other operator (Fig. 1), that is in order to satisfy customer demand, traffic is steered to the partner operator. Different cases can be realized for steering operations.

A call started from an operator may end at another operator's network. In more complex scenarios, a call starts at operator (originate), then continues at another operator and then ends in another operator (destination). In chain steering cases like this, every member of the chain should have multiple interconnect agreement between neighbour members. Agreements shall be managed by operators for cost reduction and efficient use of networks. Operators should manage these agreements in order to use their networks efficiently, reduce costs, and increase margins.

As the European Parliament's new regulation about telecommunication operator steering, which is accepted in 2017, different tariffs can be applied according to call's origin which are in the same destination group by using "a-number" information. For the sake of the operators, they started to get avoided from abuses based on permanent or residence related to an European Union country. Operators are avoided from irregular circumstances in the domestic market. Different tariffs are applied from the different origins with the same destinations. Thus, tariffs are decided by country codes or route of origination. Before this regulation is executed, B-number rating, billing and routing was being concerned by carriers. A need occurred on changing schemes and focusing on both billing type which are origin (A-number) and destination (B-number).

The problem we aim to 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 by considering the origin of the call. International call steering consists of two parts: 1) outgoing traffic steering, 2) incoming traffic steering.
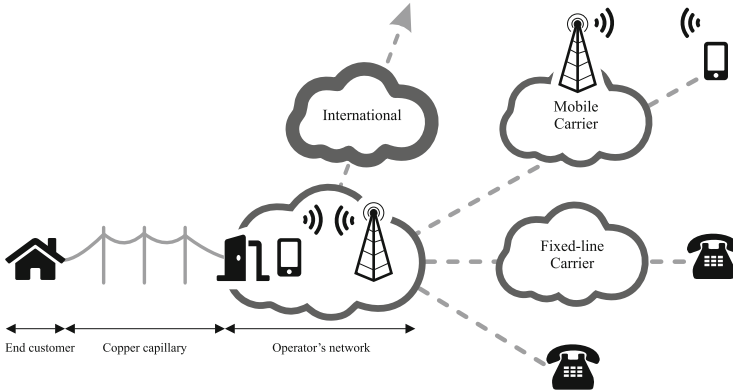
Fig. 1. Network diagram of the home operator [15].

On daily basis, outgoing traffic states the steered volume to partner operators. Home operators and partner operators have special agreements for traffic steering which are also called commitment agreements. While increasing the business volume, agreements may not point to a profit at an ongoing period. Agreements may also lead to price discounts or commercial trust in upcoming periods. Additionally, the quality aspect is leading these agreements to becomes more important on behalf of customer satisfaction. Keeping the quality on a sufficient grade at the outgoing steering decisions is crucial as the cost of the steering.

Incoming traffic steering lies outside from the focus of this study since it described in detail at [15].

2.1   Dataset

In this part, data acquisition for the inputs of the model and the properties of data are described. The objective of the model is to keep the quality level above a particular threshold level, while decreasing the traffic steering cost. In order to create the model, the following data is used:

– Unit price per minute based on origin (A-number) and destination (B-number) (Tariff)
– Locations where operators provide service
– Outgoing demand information
– Details of agreements with other operators
– Call Detail Record (to determine quality metric)

Turkcell is the market leader in the Turkish GSM market with   44% market share and the annual income of US$4.4B in 2018 [17]. In addition to the 33.8 million customers in the 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.

Call Detail Record (CDR) is a detailed dataset containing the time of call, length, competition status, source phone number, and destination phone number. In this work, CDR data is available for international traffic between 01.03.2019-30.03.2019 in worldwide. Prefixes in the CDR dataset that daily occurred steering process in one month is included in works in order to obtain meaningful forecasts. In the outgoing traffic, there are 153 operators and 2364 prefixes in the data. Also, the information about agreements of 24 operators and 279 locations are available in the data.

When the distributions of demands coming from designated areas and goes to a specific prefix, generally two characteristics is observed. Some of the demands are clearly containing seasonality, while some of them are in the wavy structure and free from the season. Examples from these two characteristics can be seen in Fig. 2a and Fig. 2b. The figures show the demand for the calls on a one-month period.

In order to test a more realistic scenario in which the decisions are made one week earlier than the actual demand realization, 1 step and 2 step forecasts are calculated by applying the rolling horizon approach using weekly, two weekly, and three weekly data.
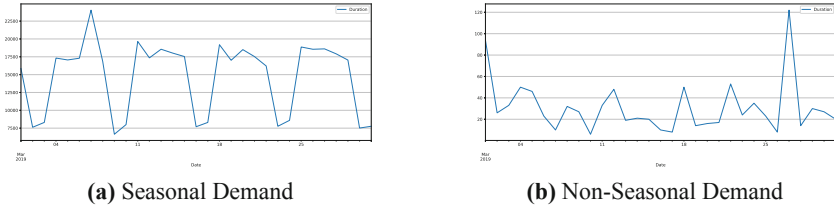

(a) Seasonal Demand   **(b)** Non-Seasonal Demand

Fig. 2. Characteristics of demand.

2.2   Demand Forecasting

We choose to utilize time series models in order to predict future demand values. Among many others, two commonly used linear time series models in the literature are Moving Average (MA) and Autoregressive (AR) models. A combination of AR and MA models, namely, Autoregressive Moving Average (ARMA) and Autoregressive Integrated Moving Average (ARIMA) models are also very frequently studied in the literature. ARIMA model can be used when the data is non-seasonal and non-stationary [2]. A different type of ARIMA, named Seasonal Autoregressive Integrated Moving Average (SARIMA), model is also proposed as a seasonal time series forecasting model [1,2,8,9]. To work with a data set with seasonal components, Box and Jenkins [1] have proposed SARIMA and in order

to eliminate non-stationary structure from the time series, seasonal differencing of appropriate order is used.

In this study, ARIMA and SARIMA models are used. After splitting the data to train and test set, we used grid search for searching parameters for ARIMA and SARIMA. For scoring and selecting the best model, the Akaike Information Criterion (AIC) scoring method is used. The method can be shown to have a basis in frequentist-based inference and information theory. To use AIC for model selection, we simply choose the model giving the smallest AIC over the set of models considered [5]. For the test set, the forecast is done with selected parameters and an appropriate model. Then, the mathematical model is fed with the corresponding forecast.

2.3   Agreements

International roaming traffic increments caused the competitive wholesale roaming sector to be reshaped. To offer better commercial solutions in the reshaped sector, trade agreements are matured and named as International Roaming Agreement (IRA). Home operators established unilateral unit prices named International Operator Tariffs (IoT). In the bilateral agreements, the large traffic volumes can push the unit prices to lower levels. Mutual commitments are the basis of these agreements.

There are four basic IRA's used in the wholesale roaming market: Quantity (QNT), Incremental (INC), Balanced/Unbalanced (BUB), and Send-or-Pay (SOP). The pricing schema of these models are given in Fig. 3. The detailed description of these models can be found in [3].

Turkcell is one of the prescriptive operators in the European region. Turkcell is using a distinguished pricing method, which is very much alike to the BUB model. However, in this specified pricing method, exceeding the volume of the commitments is paid by negotiating according to the fulfillment rates of both parties. In this method, the final cost is determined by negotiations based on business relationships. With accurate demand forecasts and minimization of the steering costs, Turkcell takes advantage in the negotiation phase.

The problem has two types of partner operators, which are committed operator (CO) and uncommitted operators (UO). There is no assurance on the service volume and tariff is priced on a minutely basis at UO. Better price on a predetermined volume of calling minutes offer is the leading sense of the agreements.

Committed operators commonly establish how the termination service will be exchanged. Compensation occurs between parties which send more and others for the amount of traffic surplus basis. For settlement purposes inter-network traffic measurements are compulsory for this fact.

In the scope of these agreements, operators agree to steer their traffic to each other in certain time intervals and particular volumes. These agreements haven't got any legal bindings but on behalf of business relations, both operators try to obey the rule of lower limits at agreements. Agreements are described in detail at [15].
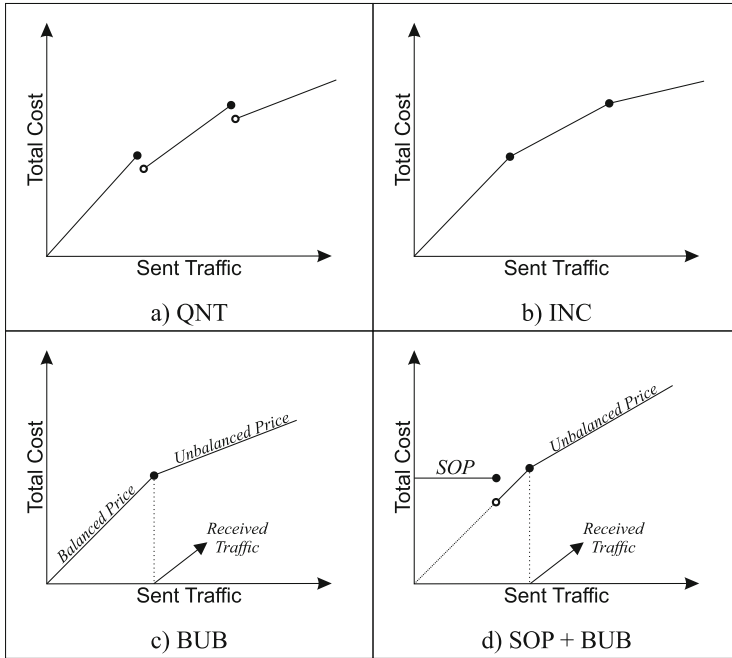The example of agreement with a CO is shown in Table 1.

Fig. 3. Payment models [3].

2.4   Analysis of Quality Metrics

There are four main quality metrics that are computed with CDR data and recommended by the International Telecommunication Union. These four metrics are Answer Seizure Ratio (ASR), Network Efficiency Ratio (NER), Average Call Duration (ACD), and Post Dial Delay (PDD) [10]. These metrics are observed in detail at previous study and concluded as using NER is more appropriate since it is more comprehensive and NER can determine threshold better while measuring network quality [15].

Measuring the capability of network calling the terminal is called Network Efficiency Ratio (NER). NER excluded customer and terminal behaviors when compared with ASR. Network Efficiency Ratio speaks better for pure network performance.

$$NER = \frac{\begin{array}{c}\text{Seizures resulting in Answer}\\ \text{message or User Failure}\end{array}}{\text{Total seizures}} \tag{1}$$

Table 1. Example of agreements with CO [15].

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		

3   A-number Steering Model with Call Quality

After data analysis and processing, a mathematical model for steering of international roaming is proposed with a cost minimization objective. The model determines steering decisions for international roaming traffic to each operator, destination (B-number), and origin (A-number) while keeping the quality on an 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 = destination prefix,
- k = destination location,
- z = origin prefix,
- P_{ij}^z = possible operator, destination prefix and origin prefix matches,
- G_{jk}^z = prefix and location matches,
- A_{ik} = operator and location matches in agreements.

Parameters:

- d_j^z = Outgoing voice demand from origin prefix z to destination prefix j,
- c_{ij}^z = Unit cost of outgoing voice traffic from origin prefix z to destination 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 destination prefix j,
- q_t = Quality threshold,
- M = Big Number.

Decision Variables:

– x_{ij}^z = 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:

$$\min \quad \sum_i \sum_j c_{ij}^z x_{ij}^z + \sum_i \sum_k M u_{ik}^+ \tag{2}$$

$$s.t. \quad \sum_{i \in P_{ij}^z} x_{ij}^z = d_j^z \qquad \forall j, z \tag{3}$$

$$\sum_{i \in P_{ij}} q_{ij} x_{ij}^z \geq q_t \sum_{i \in P_{ij}} x_{ij}^z \qquad \forall j, z \tag{4}$$

$$\sum_{j \in G_{jk}} x_{ij}^z + u_{ik}^+ \geq V_{ik} \qquad \forall i, k \in A_{ik} \tag{5}$$

$$x_{ij}^z \geq 0 \quad \forall i, j \tag{6}$$

$$u_{ik}^+ \geq 0 \quad \forall i, j \tag{7}$$

The Linear Programming (LP) model presented in Eqs. (2) through (7) aims to minimize the total steering cost and penalizes the unsatisfied agreements' volume. In the objective function (Eq. 2), Big M is a sufficiently large number that aims to firstly minimize u_{ik}^+ values (set the smallest positive values possible).

Constraint 3 ensures that the outgoing demand is met for each prefix. Constraint 4 guarantees that if steering occurs from origin prefix z to destination prefix j over operator i, the average quality of steering has to be greater than the quality threshold. Constraint 5 ensures that it satisfies the deal volume for each operator and each location. The rest of the constraints (Constraint 6 and 7) are non-negativity constraints for variables.

We implement the model by using Python 3.7 and GUROBI Solver [7] for LP. We perform all experiments on an Intel Core i7-8550U 1.8 GHz machine with 16 GB RAM.

The next section presents the scenarios we test and discussion of the findings.

4   Results

Data is applicable for international outgoing traffic. The interval of the data is 01.03.2019–30.03.2019 globally as mentioned before. The problem has definite assumptions. Firstly, the following assumptions are made for estimating the quality of the operators when historic quality data of the operators is not available: 1)If a given prefix's average quality is missing, then, the location average is used for the corresponding operator. 2) If the operator has no information about the location at all, all location's quality average is used. Secondly, steering costs are calculated based on the same exchange rate.

Results are computed under 3 different scenarios. In all 3 scenarios, the quality threshold is determined as Turkcell's historic quality average which is 78.72% and the first 10 days' data is kept for the training of the forecast model. In the first scenario, no forecast is applied and deterministic demands are directly processed in the model for 11th to 30th days. The model developed for this scenario represents the real-life scenario. In the second scenario, first, 10 days' demands are used to forecast 11th to 30th days' demands. In the third and last scenario, the rolling horizon approach is used and by using the first 10 days' data from 11th to 20th days data is forecasted while using the first 20 days' data for forecasting 21st to 30th days' data. Benchmark between results of scenarios in this study and Turkcell's independent (not using any model of this study) results are presented on Table 2.

Table 2. Total costs and Average quality rates.

	Total cost ($)	q_a (%)
Base	5,584,203.29	78.72
Scenario 1	4,912,877.89	82.23
Scenario 2	5,028,232.28	79.98
Scenario 3	4,944,826.17	81.18

Table 3. Sum of unsatisfied commitment minutes.

	$\sum_{ik} u_{ik}^+$ (min)
Base	597,831
Scenario 1	307,279
Scenario 2	384,534
Scenario 3	344,982

According to Table 2, 12.1% cost reduction is provided using a deterministic scenario in which the demand is known exactly. In the second scenario, the model resulted in 10.0% improvement containing forecast errors. In the third and last scenario improvement is increased to 11.5% containing forecast errors. The reason for this improvement is the rolling horizon approach converges to reality. In Table 3, the mentioned forecast errors can be observed for a chosen prefix.

According to Table 3, the first 10 days' forecasts look appropriate to real life, but forecasts after that converge to average demand, and the total error increases. In Graph B and C, the rolling horizon approach is presented. Demand forecasts for 11th to 20th and 21st to 30th days look similar to the real demands.

In another example, the real demands of the last 20 days for the chosen prefix are 215K min while in the second scenario forecast is 240K min and in the third
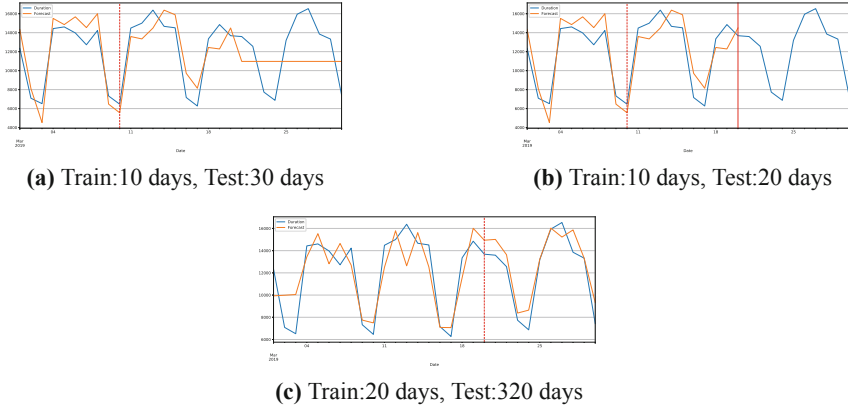
(a) Train:10 days, Test:30 days

(b) Train:10 days, Test:20 days

(c) Train:20 days, Test:320 days

Fig. 4. Train:10 days, Test:30 days

scenario forecast is 259K min. So forecast error is -5% in the first scenario while 3% in the second scenario for the corresponding prefix. The fact worthy of notice is when the forecasted demand is smaller than the actual demand, in order to fill up the agreement quotes, the developed model tries to steer calls mostly to the committed operators. In the case of high demands, since the agreement quotes will be fulfilled, the model can act more flexible in the steering decision and provides cost-benefit (Fig. 4).

When we observe all prefix's demand forecasts, the first scenario's average forecast error is 28.8%, while in the rolling horizon approach's average forecast error is 21.4%.

5   Conclusion

Operator agreements are made between contracted operators in order to decrease their service costs by steering the calls if the destination of the call is out of the operator's coverage area. The steering decision is based on the destination of the call, the price quote of the partner operator for that location, and the service quality threshold of the partner operator. Besides, according to the new law adopted by the European Commission in 2017, "a-number" which indicates the origin of the call, is also a factor for pricing. Finding the optimal steering decision under the agreement conditions and other company-specific requests is called the steering international roaming traffic (SIRT) problem.

We propose a solution to the SIRT problem with a single service by developing an optimization model that takes into account agreement constraints, a-number billing, and a quality threshold while meeting subscribers' demand over a predetermined period. Incoming steering demands are used under three different scenarios: a) deterministic demand, b) 20-day demand forecasting, generated by using 10-day data, c) the rolling horizon approach. In the rolling horizon approach, the

train data set of the forecasting model is expanded and the forecasting accuracy is improved.

The results show that the steering cost is reduced, on the average, approximately 11% although the quality of the steered calls is kept above the base quality level.

As a future step, a simulation-based decision support system may be developed to monitor how to set commitment values of future agreements under different scenarios. The developed model may also be tested with other agreement models provided in the literature. In addition, the common decisions of home operators under certain conditions could be included in the model yielding a more complex mixed-integer programming model. Assuming solving large size instances in reasonable time may not be possible, developing time-efficient heuristic algorithms will be an imminent future research direction.

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