Call-Distribution-Based View: The Theoretical Ground for Strategic Routing Management

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Abstract —This study disseminates the idea of managing the call routing problem in another perspective, which is named as the call-distribution-based view (CDBV). In this study, decision problems for telecommunications routing management are stratified into three classes; external, internal and strategic (per-se) by synthesizing two very fundamental theories: systems theory and the theory of management hierarchy. It is identified that for the strategic decisions, the top management of an operator is usually concerned with a main routing decision problem: how to decide an appropriate call distribution portfolio, as to keep the service profitable and to maintain the quality of service. Such problem involves the key performance indices of a voice service operation. It arose with the end of the monopoly in the telecommunications sector, but it is seldom addressed. Accordingly, the CDBV view is proposed to conceptualize the problem and it is shown to have decision analysis functions by a call-distribution decision case. By demonstrating that CDBV underlies an existing linear programming (LP) approach that was designed to decide the call distribution 'scenario', it is also shown to lend theoretical grounds for future problem modeling purpose. Therefore, future generalized models for determining a real optimal call distribution 'portfolio' can be expected.

Index Terms—Decision making, outbound portfolio decision, telecommunications operation, call distribution, engineering management

I. INTRODUCTION

In routing management, there are numerous decisions to make. Fortunately, these decision problems can be categorized by the nature of the questions raised and the processes to which they are relevant. They can be categorized as internal, external and strategic (per-se) problems.

Take, for example, the following related questions that an operator's decision maker (DM) might raise:

Q1: How the internal network infrastructure can be optimized?

Q2: How to interconnect with a new contracted partner efficaciously or efficiently?

Q3: What is the optimal solution of the call distribution portfolio that attains maximal profit from providing a quality service to the customers, while at the same time, paying an acceptable routing cost to the carriers?

Among which, Q3 is a question about optimal call outbound portfolio determination. It is a question that usually confounds the operators. This is because most of the contemporary operators, either large or small, suffer pressures from crucial competitions in the market, for the reason that with the end of monopoly in the telecommunications sector, there are so many operators. The answer to Q3 means an effective overall portfolio decision to guide an operator's call distribution scenario. And to decide it, it means to have a decision support function designed based on a scientific and effective decision method. However, such problem seems seldom addressed and methods to decide one such portfolio are rare.

In other words, to properly guide an operator's call distribution scenario, relevant scientific decision supports are required. But before any decision support function is designed or deployed, the decision problem, in itself, must be abstracted and conceptualized, in order to identity the relevant decision approaches for the support function.

This study serves this purpose. In this study, a view named call-distribution-based view (CDBV) is proposed. The role of it is addressed and examined. Ontologically, the core concept of this study is introduced as follows.

To theoretically classify the routing-relevant decision problems based on questions such as Q1-Q3, by approaching the telecommunication network (TN) firstly using systems theory (ST) [1], [2], the three related *link types* of call service are identified. Next, the *decision making activities* related to these questions are analyzed by the 3-level layered structure in theory of management hierarchy (TMH), which is a framework frequently used to stratify the management information system (MIS) activities [3]. With TMH, the decision activities pertaining to routing management are categorized. Finally, by *associating the link types with the decision activities,* the decision problems are classified.

Among the decision problems, the call-distribution portfolio decision, which is a strategic routing decision activity, is identified. It is a main strategic activity of the operator organization because any new call portfolio decision will affect the cost (and therefore profit), service

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quality and other performance indices for the service operation. For contemporary operators, such decision is common and frequently made because of the frequent changes, e.g., the carrier updated their price quotation and the routing cost (for the operator) increased, the competitor published a new lower tariff and the operator must follow, the customers complained the voice quality and the operator must think about routing more calls to the 'reliable carriers', and etc.

However, when the call distribution decision problem is considered, the perspective must be altered: an operator's outbound external links to a same carrier, either homogeneous or heterogeneous, must be grouped together as an abstracted 'gathered external link'. The CDBV view is proposed based on this and it forms a solid base for future decision models in solving the call distribution portfolio decision problem.

As it is shown that CDBV can be used to perform the decision analysis of an operator's call distribution scenario and with the evidence that it is able to underlie an existing linear programming (LP) approach for determining the scenario, such view is confirmed. This helps future studies establish other decision support models for a 'real call portfolio' decision, based on the management decision approaches (e.g., goal programming (GP), data-envelop analysis (DEA), game theory, analytic hierarchy process (AHP), mixed-integer programming (MIP), etc.).

The paper is organized as follow. Section 2 scrutinizes and maps the different link types to the different decision activities, so that the three classes of routing decisions can be identified. Section 3 conceptualizes the decision problem and proposes the CDBV view for the call outbound portfolio decision problem. Section 4 shows that the proposed CDBV view can be taken in practice to analyze a given decision case, while the evidence that CDBV can be used to underlie an existing LP-based model is also shown. Section 5 concludes this study.

II. The Theoretical Ground

A. Approaching the Network by Systems Theory

According to ST [1], [2], the TN can be regarded as a holistic system that is composed of many subsystems, which are the operators who provide services to the customers or other operators. In this context, every node within the topology, either an end-node or a switching node, can be viewed as a 'component'. In addition, the calls flowing between the nodes can be viewed of as the 'relationships' between these components. Fig. 1 abstracts and displays such a scenario.

As seen in Fig. 1, except for the internal nodes within an operator subsystem (u & v), the edge nodes belonging to different operator subsystems can have call flow relationships (e.g., x & y). In this study, the former relationships are defined as the *internal links* between the internal nodes of a subsystem, and the later as the *external links* to represent the relationships between the edge nodes of different operator subsystems.

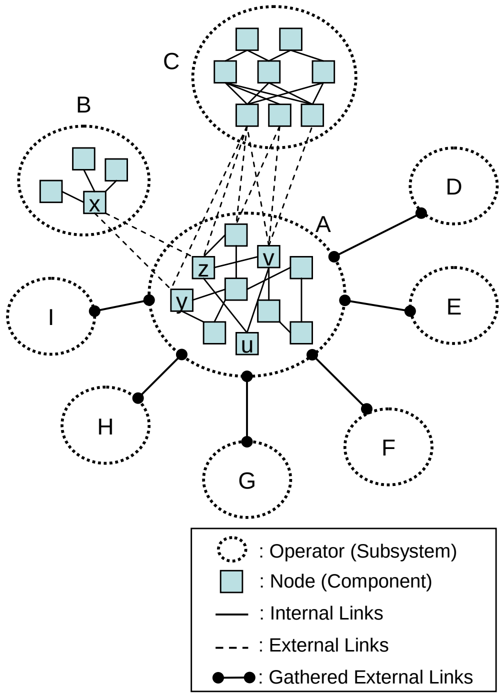

Fig. 1. Approaching the TN by ST.

In addition, when all the external links from one subsystem (e.g., operator A) to some other subsystem (e.g., operator C) are considered together, it abstractly forms a *gathered external link* (*GEL*) logically (the bold lines), with two conjunction points attached to each of the involved subsystem parties.

As the relevant link types are identified in this manner, each link type should bring up a certain type of, or certain types of, routing decision problem. In turn, every routing decision problem can be categorized according to the link type it has involved, e.g., Q1-Q3 in Section I can be categorized.

But is there any other way to categorize the routing decision problem? This is worth of further explorations.

B. Analyzing the Routing-Relevant Decision Activities

Presumably, any routing decision activity is an organizational activity [4] and is one of the main operator activities. As pioneers have pointed out that decision making is perhaps the most significant activity in company management [5], the important role of routing decision is axiomatic.

In management, a company can manage its objectives in levels of a multi-divisional hierarchy. By using a hierarchical management theory, not only the organizational objectives, but also the company activities, can be stratified into multiple layers, so can the routing decision activities of an operator.

In this study, the 3-level TMH framework in MIS decisions [3] is used to stratify the decision activities performed for routing management. In this manner, the framework contains the following three levels of routing decisions: *strategic planning layer*, *management control layer*, and *operational control layer* decisions.

For *operational control layer*, decisions are often made with respect to internal and infrastructural issues, e.g., how to optimize internal network infrastructure, or how to install new switching equipment and configure it as to put it together with other existing equipments and enable a good 'internal practice'. Thus, most decision activities in the operational control layer pertain to the problem of how, and whether, the internal links are optimized or well established, e.g., Q1. Decision problems in this layer have been tackled by some related standards (e.g., the Internet Engineering Task Force (IETF) the Open Shortest Path First (OSPF) protocol). In fact, routing decisions in this layer are usually engineering-oriented and correspond with the internal links.

For *management control layer*, decisions are often made with respect to external inter-operator issues. These can be, for example, how to interconnect with a newly contracted partner, how the topology or path of interconnected nodes (to the other subsystem) can be changed or optimized to achieve better performance, and so on. Thus, most decision activities in this layer are related to how and whether the paths or topologies within an external link are optimized, e.g., Q2. Decision problems in this layer have also been fully addressed in standard protocols (e.g., the Border Gateway Protocol (BGP) in the IETF standards). As can be seen, decision activities in this layer are also engineering-oriented issues but corresponding with the external links.

In contrast, for *strategic planning layer*, decisions are often concerned with managerial issues, e.g., Q3: "what is the optimal call distribution portfolio in consideration of maximal profit, minimal routing cost, higher service quality and better relationship with the partners?" Therefore, most decision activities in the strategic layer correspond to the problem of how, or whether, the calls on the GEL-typed links can be dealt with and well distributed. Decision activities in this layer are more business-oriented, than engineering-oriented, decision issues. Taking Q3 as an example, it is associated with neither a question about the internal links (e.g., Q1), nor a question related to external links (e.g., Q2), but is a question that is mostly related to the abstracted GEL-typed links.

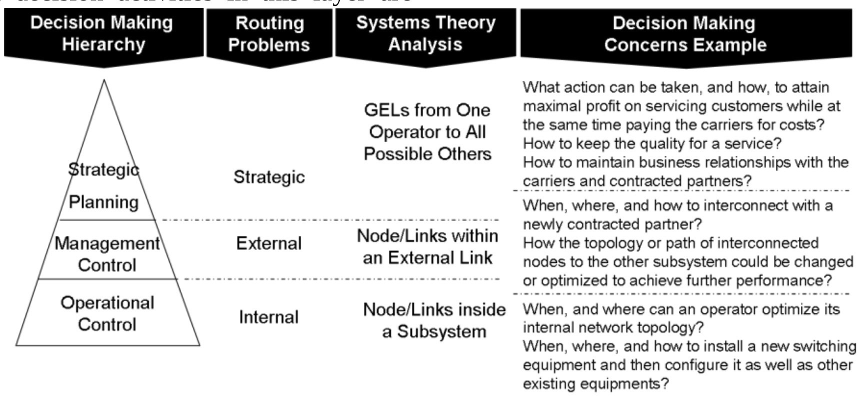

Fig. 2. Categorizing the decision problems of telecommunications routing

C. Classifications of the Routing Decision Problems

Subsection II.A shows that the three different link types yield three groups of routing decision problems and II.B shows that the three layers of decision activities also yield another three groups. Furthermore, Subsection II.B also demonstrated that these problem groups can be associated. Therefore, routing management decisions should fall in the following three classes, which are summarized as follows:

- *Internal problems*: An internal decision problem with a decision question about a link (or links) that has *internal link* property and it involves an *operational control layer* decision activity (during decision-making).
- *External problems*: An external decision problem with a decision question about a link (or links) that has *external link* property and it involves a *management control layer* decision activity.
- *Strategic (per-se) problems*: A strategic decision problem is with a decision question about one or more *GEL-typed link(s)* and it involves a *strategic planning layer* decision activity. It is also named as a 'per-se' problem because with the tough competitions, every operator's top management might be concerned with the company performance issues. These include, but not limited to, total routing cost control, overall service quality maintaining, partnership concerns of routing activities, and so on.

Such a stratification is shown in Fig. 2. While both internal and external decision problems have been conquered by well-known protocol standards, this study addresses the strategic (per-se) problems that seem relatively, infrequently mentioned.

Among all the strategic decision problems, call portfolio decision is a typical (and perhaps most critical) routing decision problem that involves the core, per-se interests of an operator. This is because it pertains to the service operation body. Any decided portfolio will guide an operator's call distribution manifests and in addition, it will definitely affect the expected overall profitability and the service quality offered. As it affects the company performance and is frequently made, a thorough study is required.

However, application studies for this problem are rare, let alone a thorough theoretical study that covers the relevant theories, lends supports to the application methods and underlies the existing decision approaches.

D. The Management Control Layer and Operational Control Layer Problems

It is noteworthy that hereinafter the management control layer and the operational control layer problems are not surveyed or discussed further, since they have been addressed by many standards, such as the BGP-4 in IETF RFC 1771, 4271 and 6286 [6]-[8] for the Internet external links between providers, the Signaling System 7 (SS7) protocols in Q.700 Series [9] for PSTN telephony and short message service (SMS), and the OSPF version 2 and version 3 correspondingly in IETF RFC 2328 and 5340 for IPv4 and IPv6 internal links within an autonomous system [10], [11].

In addition to the above standards, recent academic works also discuss some problems for the management control layer and the operational control layer. These include cost models and traffic engineering models for QoS-differentiated wholesale access services [12], wireless operator's resource allocation and control schemes in cellular networks at network level [13], the single objective model in minimizing ad-hoc radio network's bandwidth cost under least QoS requirement constraint [14], achieving efficient load balance using game theoretical framework to coordinate the routing on the links by coordinately utilizing the Multi-Exit Discriminator (MED) attribute of BGP [15], among others [16], [17].

E. Discussions about the Strategic Planning Layer Problems

In compare with the problems in the other two layers, strategic routing decision is relatively, infrequently addressed. Recent works are studying diversified strategic issues.

For example, in the recent literature, the profitability of cooperative content investment and the cooperative relay scheme for a mobile network have been studied [18], [19]. The content-variant support issue in the multimedia broadcast context and the evaluation of network/user interaction have been addressed [20], [21]. Topics about the optimal resource management for the heterogeneous networks and about the performance modeling in multi-service communications systems have been also discussed [22], [23]. Another recent research stream pertaining to strategic routing is about call center [24]-[26].

However, these topics, although strategic for an operator, are not strictly relevant to the main service body of the operator. To the best knowledge, few studies have focused on the decision of a call distribution portfolio [27]. Nevertheless, this decision should be addressed because it relates to the substantial business performance of service operations.

F. Short Summary

By scrutinizing the TN using ST, the three types of routing links (i.e., internal link, external link and GEL-typed link) are identified firstly. Next, by treating the routing decision processes as management activities and by adopting TMH, these activities are stratified into the three groups (i.e., operational control layer decisions, management control layer decisions and strategic planning layer decisions). From these works, related decision problems can be classified into three fundamental classes: internal, external and strategic decision problems.

Call distribution decision is an important strategic decision that involves the operator's core interest. Since it usually involves managerial concerns and is frequently made, it should be conceptualized in view of strategic management. Therefore, CDBV is required for abstracting the call distribution scenario of an operator, to encounter the routing behaviors over the abstracted GEL-typed links, as to underlie the decision model establishments.

III. The Call Distribution Based View

This section proposes the CDBV view. Based on ST (II.A), the assumption of CDBV is that it sees every operator as 'one single large node' in the topology. And therefore, it sees every operator as a subsystem with its own 'routing logic'.

With this 'sub-systemization' and by reference to the classification in II.C, CDBV is postulated for analyzing the strategic call-distribution portfolio decision of an operator.

A. Observations of Contemporary Operation

Some facts pertaining to current service operations can be observed, as follows:

- In contemporary operations, calls are flowing tier-by-tier from one tier to the next. No single operator of a tier possesses or is able to control the whole network.

1) This implies that a decision maker (DM) of an operator will be enforced to put the eyes on the operator's performance per-se. Among these problems, the call distribution decision will be the focus because it is a decision to determine the whole scenario of the service operation manifests and to realize the required operational performance. The main objectives of this decision are to reduce the cost, to make the service profitable, to have better service quality as well as to maintain the partnerships with other service providers, e.g., content providers, carriers, and etc.

2) Although no single operator can control the whole network, for each operator, relevant routing manifests are fully controllable. This means that changing the settings of its own routing system to meet the desired call distribution scenario is not time-costly. Therefore, it is

perhaps the fastest and easiest way to succeed in controlling the cost or improving service quality in time.

- Due to the IP-based interconnectivity, for the operator *subsystem*, the call distribution function has become more complex. When serving a call request, there are multiple service providers to choose from. These service providers can induce different routing costs and render different service qualities. This fact has burdened the DMs. And to make a call-distribution decision, the multiple criteria and the multiple decision objectives present must be taken into account all together. Based on a literature study, perhaps there is only one recent work [27] that has studied the call distribution problem over the multiple available carriers, encountering criteria and the objectives such as costs, voice quality (VQ) [28], business-concerns, and so on. The study took linear programming (LP) to construct a model and mathematically proved that modeling the call distribution decision with a 'per-time-unit' measure is tantamount to modeling the same problem with the 'total-volume' measure. But the mentioned study seems too limited because it might have left out a very critical point: how the model was constructed and what is the theoretical ground of the proposed LP approach?
- Since the operator is one of the many tiers via which a call *flows*, the operator distributes the call intelligently according to a pre-deployed routing logic (of the operator subsystem), to the service providers in the next tier. By defining each entry in the numbering plan [29] as a 'service identifier' (SI), the traffic redirection settings (forwarding logic) for each SI can be treated as a sub *routing logic* for that SI inside the routing logic. Therefore, in the TN, an actual call may flow through some successive sub routing logics from the call source to the destination tier-wisely.

B. The Abstraction of Operator's Routing Logic

To illustrate the above observation points, the *routing logic* of an operator subsystem can be abstracted in Fig. 3. In this figure, axis *t* represents the time axis. Calls from the *call receiving end*, which span over axis *t*, arrive at the routing logic arbitrarily. Each call follows to possible carriers (i.e., A, B, C and D) upon the SI and is distributed intelligently based on the *sub routing logic* defined by the operator. The thin arrows represent in-bound traffic from the call receiving end while the thick arrows refer to the possible out-bound paths to the *call distribution end*. For example, the first call with SI=49 could be routed to carrier A or C by the SI-49 sub routing logic.

As seen from the abovementioned, when one focuses on how calls are being distributed, the operator subsystem which "*distributes the receiving end calls to the distribution end for every SI*" can be conceptualized as a routing logic, regardless of the complicated incoming-outgoing link relationships and regardless of the complicated call flows inside or outside the logic. The treatment that "*an abstracted, conceptual routing logic for each operator subsystem that contains many (also abstracted) sub routing logics for every SI, which distributes calls from the receiving end to the distribution end*" forms exactly the definition of 'CDBV' referred to.

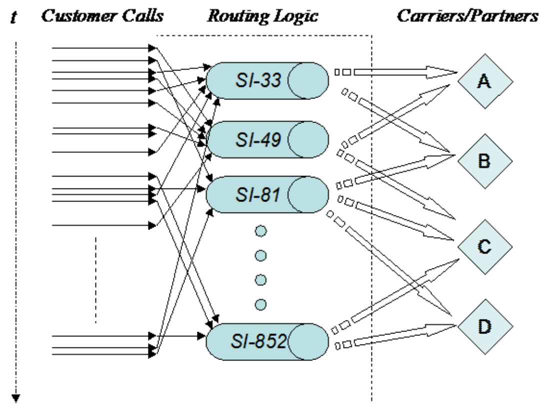

Fig. 3. Per-operator applying its own routing logic.

C. Discussions

Synthesis of theories is not a new idea. Some syntheses are functional and some might have synergistic output. Centuries ago, two law theories, the law of equity (actually an altered concept of law) and the common law, were successfully synthesized to form the current basis of law in England [30]. In recent decades, researchers have found that two or more theories can be synthesized, to have a new theory and the synthesis can be meaningful and fruitful [31]. In particular, when the perspective to a problem is altered and a theory based on such a new viewpoint is propounded, related researches for the theories synthesized or for the new theory based on the new view can be exerted. Many successful studies have been based on this principle [32]-[34].

In this study, the ST theory in the IS field and the TMH theory in the Management field are synthesized ontologically. And CDBV, as the synergistic output of two theories, is propounded based on this. This can be read from Section II, which would have presented the theoretical analysis of CDBV. And in Section V, the theoretical map of this study is shown.

Except for this, the methodological contribution of CDBV can be addressed, too. CDBV treats an operator's entire routing subsystem as a routing logic, with relevant GEL-typed links attached. This conceptualization is important for studying existing or future decision approaches or models for the encountered problem, in that it offers a simpler way to handle the multiplicity of facts pertaining to the routing systems of an operator.

As such, during decision model construction, with CDBV, the focuses are those abstracted GEL-typed links, rather than the internal links or external links of an operator. Facts and parameters can be measured or analyzed based on the GEL link units. Relevant decision criteria or goals (e.g., about routing cost, service quality, partnership volume guarantee, or etc.) can be also set directly and clearly by referring to these GEL links. This can lead to a scientific, instead of an experiential, call distribution decision. In addition, analyzing or modeling one such decision with CDBV will definitely reduce the complexity of the decision process, since the number of the abstracted GEL-typed links should be far lesser than the number of those real internal or external links.

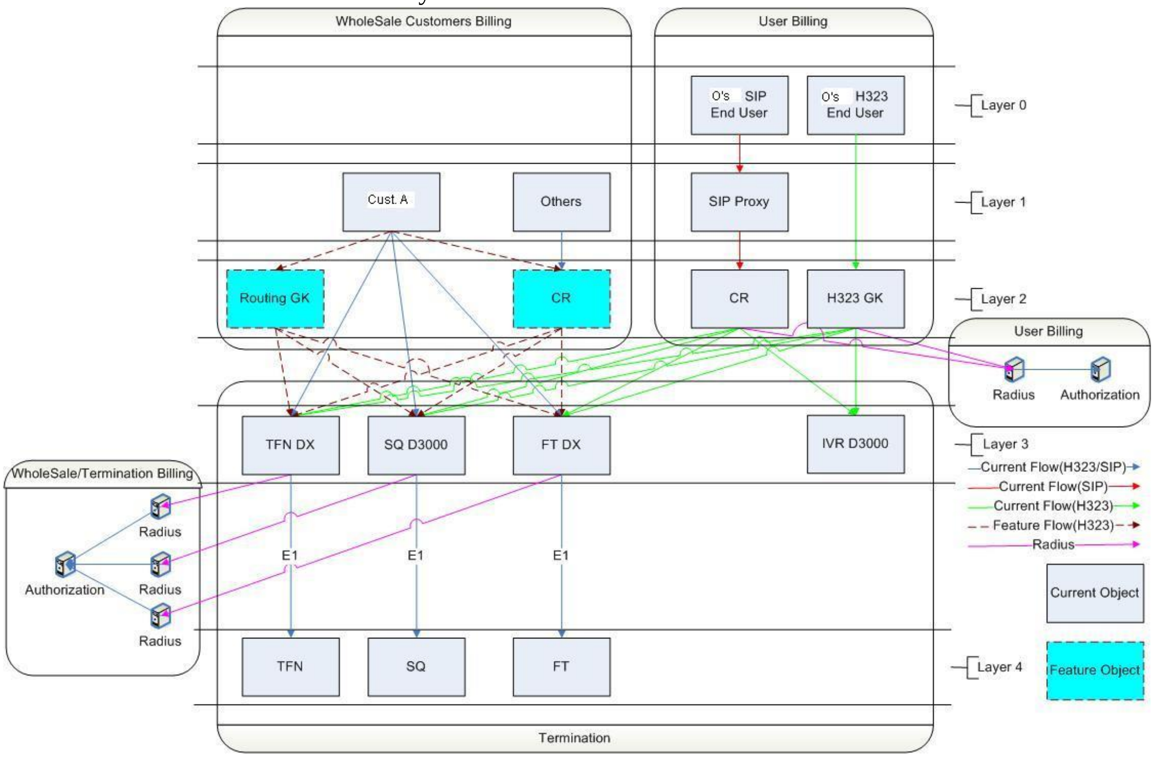

Fig. 4(a). A sample infrastructure from a sample service operation of a sample operator O

IV. The Evidences

To demonstrate that CDBV does mean a lot, this section gives out two evidential cases for it. One is for showing the way in which it can support the decision analysis of an operator's call distribution scenario. The other is for demonstrating that it underlies an existing modeling approach for the decision, in which the theoretical ground of one such approach is still unidentified.

A. Decision Analysis Based on the Application of CDBV to a Real Operator Case

An operational infrastructure sampled from a real operator, O, is shown in Fig. 4(a). As can be seen, there are cleanly layered equipments and switching systems. As defined by the operator, Layer 0 contains the end user clients or devices. Layer 1 contains SIP proxies on which the user can register and the equipments possessed by other operator parties that can send in the IP-based voice calls, which can be also virtually regarded as Layer 1 equipments. Layer 2 contains switching functions that can switch the IP-based calls received from Layer 1 to Layer 3. Layer 3 contains termination equipments (owned by the operator and on the IDC racks), either terminated locally (e.g., the IVR server) or terminated remotely via the digital links to Layer 4, which are the peer equipments offered by the carriers.

In this operator case, the previous engineering routing works were always focused on the complicated internal links between Layer 2 (the switching equipments) and Layer 3 (the operator-end call termination devices). Other engineering-oriented routing works were always focused on improving or provisioning the external digital links toward the contracted partners (carriers). As for the tariff negotiation that defines the per-SI routing cost for the calls terminated to each partner, it is another job done by the marketing department.

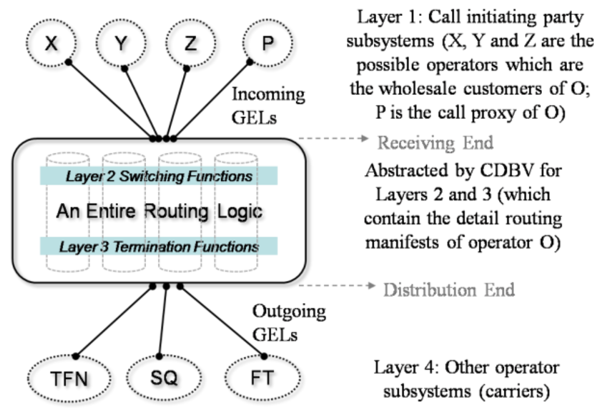

Fig. 4(b). Applying CDBV for operator O.

However, with CDBV, the perspective can be altered. The whole structure, Layers 2 and 3 can be regarded as an entire routing logic that connotes the operator subsystem with many programmed and exercised sub routing logics. Such conceptualization is shown in Fig. 4(b). In addition, the digital links simplified as ‘E1’ between Layers 3 and 4 are the abstracted GELs in which call distribution takes place. Therefore, a portfolio describing how the traffic is distributed over these GELs is required for the strategic routing management. Note that in Fig. 4(a), an ‘E1’ mark may connote multiple digital lines, depending on the capacity of the Layer 3 equipment.

For example, by routing the SI=49 customer calls, the ‘voice quality scores’ were recorded by the Layer 3 equipments. And based on the historical database, the voice quality on routing the SI=49 calls to each of the three carriers (i.e., TFN, SQ and FT shown in Layer 4) can be averaged, to have three predicted scores. Each of which indicates the expected voice quality when in the future any SI=49 call is to be routed (e.g., the average scores of TFN, SQ and FT on servicing SI=49 are 87.8, 84.2, 78.8, respectively). Therefore, when any call distribution portfolio is available or determined, the “expected average voice quality” of this portfolio can be easily predicted. Take, for example, if 60% of the SI=49 traffic was forwarded to TFN, 30% was to SQ and 10% was to FT, the expected average voice quality of this portfolio would be (87.8x0.6+84.2x0.3+78.8x0.1)=85.82.

In addition, the average expected routing cost can be also predicted based on CDBV. For example, given the abovementioned call distribution portfolio (i.e., 60%, 30% and 10%), it can be predicted that the “average expected minute cost” of this portfolio should be (3.6x0.6+3.4x0.3+3.1x0.1)=3.49 cent. This is calculated based on the contracted carrier tariff sourced from the marketing department, which states that TFN offers 3.6 cent per minute for the SI=49 terminations, while SQ offers 3.4 cent and FT offers 3.1 cent.

TABLE I: THE INITIAL PORTFOLIO AND ITS RESULTS

Service Provider	Initial Portfolio		
	Portfolio (%)	*Cost (cent)*	*Score*
TFN	60%	3.6	87.8
SQ	30%	3.4	84.2
FT	10%	3.1	78.8
Expected Average		3.49	85.82

TABLE II: THE REVISED PORTFOLIO AND ITS RESULTS

Service Provider	Revised Portfolio		
	Portfolio (%)	*Cost (cent)*	*Score*
TFN	65%	3.6	87.8
SQ	25%	3.4	84.2
FT	10%	3.1	78.8
Expected Average		3.5	86.0

If operator O has two strict goals in deciding the portfolio: the average expected minute cost must be no more than 3.5 cent and the average expected voice quality score should be no less than 86.0, then the (60%, 30%, 10%) portfolio is slightly short to meet voice quality criteria because 85.82<86.0, although the cost criteria is satisfied (3.49<3.5). It must be tuned. For example, a revised portfolio of (65%, 25%, 10%) might be therefore preferred because it just leads to an expected per-minute cost of 3.5 cent and an expected voice quality score of 86.0. These results are summarized in Table I and Table II.

As can be seen in this example case, researchers and practitioners have already solved the internal routing decision problems of the composite neurons within operator O’s subsystem structurally, and have optimized the external routing problems between the operator subsystem and any other subsystem topologically (the complex interconnections wrapped inside each “external link”). Despite so, it is necessary to study the operator’s “per-se” problem, which is about how to distribute calls properly onto/toward the outgoing GELs. In the strategic planning layer, DMs can neither do anything about the outside topology of the network, nor optimize any external link (since it is usually ‘offered’), but can pay close attentions to their issues “per-se”, especially in regard to the parsimonious decision-making concerns of cost, profit, service quality, business contracts, and so on.

In addition, CDBV is shown able to analyze the different call portfolio decisions of operator O. This implies that for the operators, it can support the analysis of different call distribution decision scenarios.

Moreover, the above fact implies that with CDBV, the outbound portfolio decision can be scientifically managed. As discussed previously, given the context of multiple service providers which offer different service qualities and induce different costs and the multi-criteria, multi-objective decision context, experiential decisions for portfolio determination would be inappropriate. Instead, scientific decisions should take the place.

As shown by the above examples, CDBV not only supports the decision scientifically (i.e., the DMs can try some different portfolios and see the expected results), but also simplifies the relevant decision works (inter-departmental processes are simplified and in particular, the diversified opinions can be converged). It resolves the decision problem in one stop and offers a clear guide for engineering manifests.

However, merely supporting decision analysis is not enough for CDBV. It had better support decision modeling, too.

B. Decision Modeling Support

By observing that the CDBV view underlies an existing mathematical modeling approach to decide a call distribution scenario, it is evident that CDBV is able to support decision modeling, too.

In Chang et al. [27], there is a LP model proposed for deciding the scenario, named (P3) in the article, as follows:

(P3)

$$Min \quad |c'(x) - G'c| + |s'(x) - G's| + |b'(x) - G'b|$$

s.t.,

$$c'(X)=\sum_{i=1}^{n}c_i x_i \quad (1)$$

$$s'(X)=\sum_{i=1}^{n}s_i x_i \quad (2)$$

$$b'(X)=\sum_{i=1}^{n}b_i x_i \quad (3)$$

where $X \in F$ is a feasible set.

In the model, n is the number of available carriers. x_i is the decision variable connoting the traffic percentage routed by some i-th carrier for some specified SI. c_i is the per-time-unit routing cost for that SI when a call is routed to the i-th carrier. s_i is the voice quality for that SI when a call was routed to the i-th carrier. b_i is some other measured quantitative business parameter for the i-th carrier route.

As can be seen in the model, there are three criteria in the model, namely, cost criteria, voice-quality criteria and the business criteria. The formulations of these criteria (i.e., the criterion functions) are Eq. (1), (2) and (3), correspondingly. In addition, *G'c*, *G's* and *G'b*, respectively, connote the aspired goals of these criteria (e.g., the aspired voice quality score for *G's*, 86.0 and the expected per-minute routing cost for *G'c*, 3.5 cent, as discussed in IV.*A*). So the objective function of the model is to minimize the summation of the absolute distances between the values of each criterion function and the levels of each goal, given that X is a decision vector: (x_1, x_2, .., x_n).

When observed deeply, if Eq.(3) is removed from the (P3) model and another constraint equation, "$x_1+x_2+x_3=1$ (100%)" is added, it becomes exactly a decision model that serves the call portfolio decision purpose of the example used in IV.*A*. That is, given n = 3, C = (c_1, c_2, c_3) = (3.6, 3.4, 3.1) and S = (s_1, s_2, s_3) = (87.8, 84.2, 78.8), G = (G'_c, G'_s) = (3.5, 86), the decision model can be constructed as follows:

(Distribution Portfolio Decision Model for Operator O)

$$Min \ \ |c(X)-3.5|+|s(X)-86.0|$$

s.t.,

$$c(X)=3.6x_1+3.4x_2+3.1x_3$$

$$s(X)=87.8x_1+84.2x_2+78.8x_3$$

$$x_1+x_2+x_3=1$$

where $X \in F$ is a feasible set.

This model shall obtain an optimal portfolio solution X^* = (0.65, 0.25, 0.1), as shown in Table II. Of course, the model might obtain other optimal solutions that achieve the goals at the same levels, if the optimal frontier constitutes of multiple points.

The above discussions show that model (P3) can be construed based on the CDBV view, but for any possible reason, the authors of [27] might have failed to mention this. As is seen, with a slight modification, (P3) will become a call portfolio decision model.

In addition, according to the original definition of (P3), it relies upon the different measurements which are based on "for some SI when a call is routed to the i-th carrier" and more interestingly, the decision variable, x_i, is defined as "the traffic percentage routed by some i-th carrier for some specified SI". Such definition of the decision variables, i.e., in terms of 'traffic percentage', in itself, implies that the decision vector, X, which connotes the "call distribution scenario" (as defined in the study), is by some means a 'portfolio'. But it is not a real 'portfolio' because its elements (the traffic percentages) do not sum up to 1.

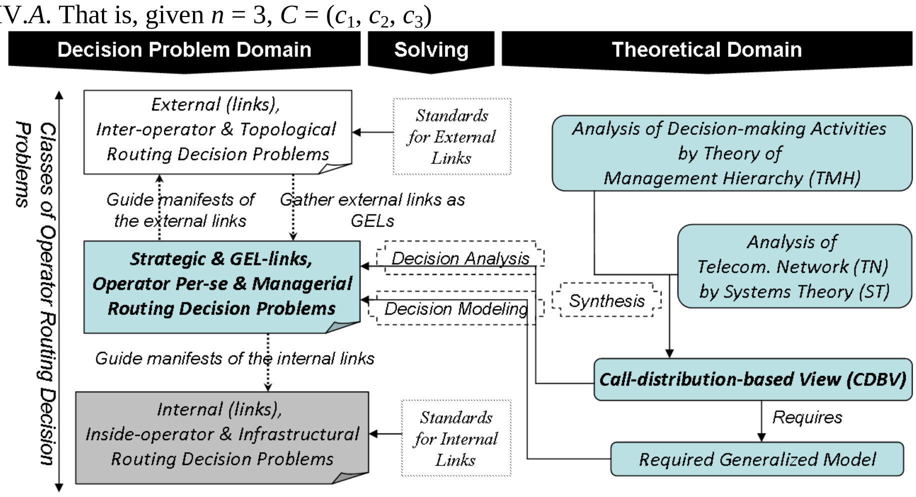

Fig. 5. The theoretical map of this study.

In a short summary, it is evidential that CDBV does underlie an existing LP-based decision model for solving the call distribution problem. This implies that CDBV is perhaps an effective view to underlie other, perhaps future, models which aim to determine the optimal call distribution portfolio for an operator.

V. Conclusions

In this study, the call distribution portfolio decision that pertains to the abstracted GELs is studied and the CDBV view, which stands on the core interests of an operator, is proposed. Since the top management of an operator company would be mostly concerned with the performance issue per se, CDBV can be used to analyze the strategic portfolio decisions as well as to ground relevant call-distribution decision models.

In addition, CDBV implicitly introduces a “middle layer” (of the GELs) between the outside topology and the inside infrastructure of an operator. Although this layer might be somehow invisible from the engineering point of view, it is clearly seen from the management perspective and it has to be modeled. This invisible layer is shown together with the theoretical map of this study in Fig. 5.

Finally, some further research directions can be considered.

1) Generalized decision model. A general model to determine the call distribution portfolio is required. This model should take account of the GELs mathematically, meet the DM’s expectations (decision goals) effectively, deal with the presented constraints/criteria systematically, and obtain the portfolio decision scientifically. It should also be easily integrated with the operation support system (OSS) of an operator.

2) Decision factors. With CDBV, other than cost and voice quality, a multiplicity of relevant decision factors can be taken into account, such as post dialing delay, answer-seizure ratio, routing quota concern, network quality, to name but a few. Factor dependency, criteria priority and factor clustering are also good future research topics.

3) Approaches for decision modeling. Since the problem is a multi-criteria and multi-objective decision, goal programming (GP) [35]-[37] or its relevant decision approaches can be considered as the modeling approach, as it is an effective tool to model many real world decision problems [38]-[41].

REFERENCES

[1] R. L. Ackoff, “Toward a system of systems concepts,” *Management Science*, vol. 17, no. 11, pp. 661-671, 1971.

[2] M. Bunge, Treatise on Basic Philosophy: Volume 6: Epistemology and Methodology II: Understanding the World, U.S.: Springer, 1983.

[3] G. A. Gorry and M. S. S. Morton, *Management Decision Systems: A Framework for Management Information Systems*, U.S.: MIT, 1970.

[4] E. Yuchtman and S. E. Seashore, “A system resource approach to organizational effectiveness,” *American Sociological Review*, vol. 32, no. 6, pp. 891-903, 1967.

[5] H. A. Simon, *The New Science of Management Decision*, U.S.: Prentice Hall, 1977.

[6] E. Chen and J. Yuan, RFC 6826: Autonomous-system-wide unique BGP identifier for BGP-4, IETF Standards Track, 2011.

[7] Y. Rekhter, T. Li, and S. Hares, RFC 4271: A Border Gateway Protocol 4 (BGP-4), IETF Standards Track, 2006.

[8] Y. Rekhter and T. Li, RFC 1771: A Border Gateway Protocol 4 (BGP-4), IETF Standards Track, 1995.

[9] Telecommunication Standardization Sector, ITU-T Recommendation Q.700 Series, ITU-T Publications, 1980.

[10] R. Coltun, D. Ferguson, J. Moy and A. Lindem, RFC 5340: OSPF for IPv6, IETF Standards Track, 2008.

[11] J. Moy, RFC 2328: OSPF version 2, IETF Standards Track, 1998.

[12] A. E. Garcia, L. Rodriguez, and K. D. Hackbarth, “Cost models for QoS-differentiated interconnecting and wholesale access services in future generation networks,” *Telecommunication Systems*, vol. 51, no. 4, pp. 221-231, 2012.

[13] M. A. Khan, A. C. Toler, F. Sivrikaya, and S. Albayrak, “Cooperation-based resource allocation and call admission for wireless network operators,” *Telecommunication Systems*, vol. 51, no. 1, pp. 29-41, 2012.

[14] L. M. Xie, X. H. Jia, and K. X. Zhou, “QoS multicast routing in cognitive radio ad hoc networks,” *International Journal of Communication Systems*, vol. 25, no. 1, pp. 30-46, 2012.

[15] S. Secci, J. L. Rougier, A. Pattavina, F. Patrone, and G. Maier, “Multi-exit discriminator game for BGP routing coordination,” *Telecommunication Systems*, vol. 48, no. 1-2, pp. 77-92, 2011.

[16] A. Gunnar and M. Johansson, “Robust load balancing under traffic uncertainty—tractable models and efficient algorithms,” *Telecommunication Systems*, vol. 48, no. 1-2, pp. 93-107, 2011.

[17] D. Santos, A. DeSousa, F. Alvelos, M. Dzida, and M. Pióro, “Optimization of link load balancing in multiple spanning tree routing networks,” *Telecommunication Systems*, vol. 48, no. 1-2, pp. 109-124, 2011.

[18] H. LeCadre and M. Bouhtou, “Modelling MNO and MVNO’s dynamic interconnection relations: Is cooperative content investment profitable for both providers?” *Telecommunication Systems*, vol. 51, no. 2-3, pp. 193-217, 2012.

[19] B. Y. Liu, V. S. Feng and S. Y. Chang, “Performance analysis for relay networks with hierarchical support vector machines,” *International Journal of Communication Systems*, vol. 26, no. 3, pp. 337-355, 2013.

[20] G. Xylomenos, K. Katsaros, and V. Tsakanikas, “Support of multiple content variants in the multimedia broadcast/multicast service,” *International Journal of Communication Systems*, vol. 24, no. 6, pp. 691-708, 2011.

[21] S. Hatakeyama, C. Takano, and M. Aida, "Hierarchical performance evaluation method for describing the interactions between networks and users," *Journal of Communications*, vol. 9, no. 10, pp. 737-744, 2014.

[22] X. Y. Yu and H. B. Zhu, "Optimal resource management with delay differentiated traffic and proportional rate constraint in heterogeneous networks," *Journal of Communications*, vol. 9, no. 9, pp. 714-722, 2014.

[23] S. Yang and N. Stol, "Performance modeling in multi-service communications systems with preemptive scheduling," *Journal of Communications*, vol. 9, no. 6, pp. 448-460, 2014.

[24] V. Mehrotra, K. Ross, G. Ryder, and Y. P. Zhou, “Routing to manage resolution and waiting time in call centers with heterogeneous servers,” *Manufacturing & Service Operations Management*, vol. 14, no. 1, pp. 66-81, 2012.

[25] D. Zhan and A. R. Ward, “Threshold routing to trade off waiting and call resolution in call centers,” *Manufacturing & Service Operations Management*, vol. 16, no. 2, pp. 220-237, 2013.

[26] B. Legros, O. Jouini, and Y. Dallery, “A flexible architecture for call centers with skill-based routing,” *International Journal of Production Economics*, vol. 159, pp. 192-207, 2015.

[27] C. T. Chang, Z. Y. Zhuang, and H. M. Chen, “A goal programming modeling for telecommunication routing management,” *World Academy of Science, Engineering and Technology*, vol. 75, pp. 506-514, 2011.

[28] L. F. Zhou, L. Chen, H. K. Pung, and L. H. Ngoh, “Identifying QoS violations through statistical end-to-end analysis,” *International Journal of Communication Systems*, vol. 24, no. 10, pp. 1388-1406, 2011.

[29] Telecommunication Standardization Sector, ITU-T Recommendation E.164, ITU-T Publications, 2005.

[30] R. Huang, *1587: A Year of no Significance*, U.S.: Yale University Press, 1987.
[31] M. Bunge, Treatise on Basic Philosophy: Volume 4: Ontology II: A World of Systems, U.S.: Springer, 1979.
[32] N. Boubakri, "The financial and operating performance of newly privatized firms: evidence from developing countries," *Journal of Finance*, vol. 53, no. 3, pp. 1081-1110, 1998.
[33] S. Nevo and M. R. Wade, "The formulation and value of IT-enabled resources: antecedents and consequences of synergistic relationships," *MIS Quarterly*, vol. 34, no. 1, pp. 163-183, 2010.
[34] M. Gervais, Y. Levant, and C. Ducrocq, "Time-driven activity-based costing (TDABC): An initial appraisal through a longitudinal case study," *Journal of Applied Management Accounting Research*, vol. 8, no. 2, pp. 1-20, 2010.
[35] A Charnes and B. Collomb, "Optimal economic stabilization policy: Linear goal-interval programming models," *Socio-Economic Planning Sciences*, vol. 6, no. 4, pp. 431-435, 1972.
[36] C. Romero, "Extended lexicographic goal programming: A unifying approach," *Omega*, vol. 29, pp. 63-71, 2001.
[37] C. T. Chang, H. M. Chen, and Z. Y. Zhuang, "Revised multi-segment goal programming: Percentage goal programming," *Computers and Industrial Engineering*, vol. 63, no. 4, pp. 1235-1242, 2012.
[38] S. P. Wang, Y. K. Hsieh, Z. Y. Zhuang, and N. C. Ou, "Solving an outpatient nurse scheduling problem by binary goal programming," *Journal of Industrial and Production Engineering*, vol. 31, no. 1, pp. 41-50, 2014.
[39] C. T. Chang, Y. Y. Chou, and Z. Y. Zhuang, "A practical expected-value-approach model to assess the relevant procurement costs," *Journal of the Operational Research Society*, 2014.
[40] C. T. Chang, C. K. Chung, J. B. Sheu, Z. Y. Zhuang, and H. M. Chen, "The optimal dual-pricing policy of mall parking service," *Transportation Research Part A*, vol. 70, no. c, pp. 223-243, 2014.
[41] J. Das, "Optimization of geodetic quadrilateral using goal programming," *Journal of Mines, Metals and Fuels*, vol. 61 no. 4, pp. 88-92, 2013.

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