Ontological Evaluation of the ITU-T Recommendation G.805

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***Abstract* —The ITU-T Recommendation G.805 is a telecommunication standard providing a generic functional architecture for transport networks and serving as the basis for several others networking and management specifications. Due to its fundamental importance, it is essential for this recommendation to be clear, complete and unambiguous, thus eliminating the spread of problems for all its using documents. This article employs an ontology-based systematic evaluation to verify the aforementioned characteristics on the ITU-T G.805 standard current documentation. Moreover, it discusses a number of ontological problems identified by this evaluation. Finally, the article illustrates with fragments of a well-founded reference model for the same domain, how these identified problematic situations can be addressed in a representation artifact.**

Keywords — Transport Networks, ITU-T G.805, Ontology Model, Ontological Evaluation .

I. INTRODUCTION

The increase of web based applications and the use of dynamic networks has demanded interoperability and reusability of Transport Networks systems and processes. The need for Control Plane and federated networks Management Plane interoperation brings new challenges. On the other hand, the lack of harmony between concepts, processes and standards, used in each entity of the federation, delays initiatives such as Autonomic Networks and Business Driven Networks.

To the telecommunications community, specifications are documents with the objective of describing in human terms a specific technology. These documents are usually produced in a natural language (e.g. English), which is a suboptimal move, given that natural language´s notorious ambiguity can entail doubts and misunderstandings in their interpretation. This, in turn, can directly and negatively impacts the quality of products and process which are based on this specification.

An example of a specification in the aforementioned sense is the ITU-T Recommendation G.805 [1]. This specification is fundamental to various telecommunications network technologies since it presents a generic architecture for transport networks. This architecture, in turn, serves as a basis for several other recommendations that standardize specific technological platforms (e.g., SDH and OTN), network management, performance evaluation and functional specification of equipment.

However, despite the visible importance of this recommendation, its text does not contemplate an adequate and precise information model for the represented domain concepts. As result, that document has ambiguities, contradictions, representation gaps, and inconsistencies. A base recommendation that presents ontological problems (i.e. problems on its foundation) will propagate these problems to all its using recommendations, and can generate applications or specifications with failures.

Recently, there has been a growing interest in the use of Ontology-Based Techniques for the systematic evaluation of a number of domain representation artifacts, including: general purpose and domain specific modeling languages [2], simulation frameworks [3], as well as reference information models [4,5,6]. The idea is that building a domain representation artifact by using well-founded ontological techniques can significantly contribute for guaranteeing that these artifacts preserve not only an intrinsic logical consistency (within the model) but also ontological consistency. Logical consistency address, for instance, the issue of whether the model lacks logical contradictions, whether it is satisfiable, etc. In contrast, ontological consistency address whether, for instance, all lifetime dependent elements in the model exist only when their dependees exist, or whether a rigid type (one that cannot chance its instance) is indeed instantiated by the same entities in all possible situations. For an in depth introduction to the topic of ontology-based information models, one can refer to [7].

A. Related Work

The work presented in [8] shows an application of ontology technologies in the domain of optical transport networks based on the standards ITU-T G.805 and ITU-T G.872. However, in sharp contrast with the work presented here, that work does not aim at producing a reference conceptual model of those recommendations in a true ontology-based modeling language. In other words, the models in [8] are merely initial OWL implementation of those standards which are, hence, bound by the limitations of that language in terms of expressivity and methodological support. As consequence, those implementations serve different purposes than supporting the proper analyzes of semantic problems in those standards.

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In a previous article [9], we present an Ontology-Based Reference Conceptual Model for the ITU-T Recommendation G.805. The article presents the modeling of the recommendation main concepts, properties, relationships and constraints. Moreover, it presents a number of inference rules that can be used for automatically deriving new knowledge from the explicitly represented model. Finally, the paper shows an illustrative intelligent implementation based on an implementation of that reference model in the formal W3C languages OWL/SWRL (see http://www.w3c.org).

B. *Contribution of This Paper*

As an additional benefit of employing rigorous ontology techniques in the construction of the model in [9], we managed to identify a number of deficiencies (e.g., imprecision, semantic ambiguity, incompleteness) in the G.805 specification. One of goals of this article is to report on these findings. In particular, we employ here the aforementioned reference model as well as the ontology-based evaluation framework proposed in [7] to systematically assess a number of properties of the ITU-T G.805 Standard Recommendation. The framework employed is termed Ontology-Based because it uses an Ontology-Based Conceptual Model of the domain as a reference model for analyzing a representation artifact for that domain by assessing a number of formal properties that should be preserved in the mapping between these two entities (i.e., the level of homomorphism between the reference model and the representation artifact) [7].

C. *Text Organization*

As a point of terminological clarification, in the remainder of this article, we use the term **Subject Domain** or **Universe of Discourse** to refer to an abstract conceptualization shared by a community of users and which is intended to be represented by a representation artifact [7]. In this particular case, the Domain Conceptualization is the one of Transport Networks, more specifically its generic architecture as seen by the ITU-T Recommendation G.805. Moreover, the term **specification** is taken here to represent the official standard representation of this conceptualization. In this case the ITU-T Recommendation G.805 Official Document. Finally, a **conceptual model** for this domain of conceptualization, according to a given standard specification and constructed using a number of ontology-based techniques is termed here simply a Reference Conceptual Model.

Section II of the paper briefly presents the technical background on the ITU-T Recommendation G.805 and on the importance of a well-founded Reference Model. It also presents the framework used for the ontological analysis and evaluation which is later employed in Section III. Section III is the main section of this work, presenting the analysis of the G.805 Recommendation and pointing to its identified deficiencies. Moreover, the section also presents cases of problematic definitions identified in the standard and demonstrates how these problems have been eliminated in the reference model proposed in [9]. Finally, in section IV, conclusions and are presented.

II. TECHNICAL BACKGROUND

A. *The ITU-T Reccomendation G.805*

Chapter 5 of the ITU-T G.805 Recommendation defines a generic model for describing the transport network architecture. This functional and structural model provides a high level of abstract view for the basic elements in a network and defines relevant concepts to simplify network descriptions. Examples of such concepts include **Partitioning** (some elements can be part of others or be composed of others) and **Layering** (each technology is inside a Layer and different aspects of a complex network can be viewed from different Layers). Furthermore, the recommendation defines the client-server relationship between vertically adjacent Layers.

The independence of the architecture model from specific technologies is a relevant feature. The model provides means to describe different kinds of complex transport networks. This feature allows the G.805 to be used as the basis for other technology specific recommendations, such as the ITU-T Recommendation G.872, named "Architecture of optical transport networks" (OTN). In addition to the textual (i.e., natural language) description of the main concepts and relationships, the ITU-T G.805 also contains a visual language to (allegedly) support a better understanding of the document. This language, however, is also completely devoid of formal semantics.

Many definitions and concepts in ITU-T Recommendation G.805 are recursive. They keep the model abstract and neutral with intention of making it valid for the majority of specific technology used in transport networks. Examples of that feature are the orthogonal concepts of Network Partitioning (horizontal recursive definition) and Layering (vertical recursive definition). In this vertical view, the Layering concept organizes a transport network in adjacent layers, separating different technologies and network protocols. However, each layer is described using the same basic and abstract elements, making it easier to model multi-technology networks. In the horizontal view, the Partitioning concept, organizes the topological elements on a network layer. Partitioning is important to describe routing aspects, administrative domain boundaries and the subnetwork (a recursive definition for a not well-known network, e.g. a cloud network).

The flow of information between the two ends of the network (source and sink), is performed through adjacent layers up to the real (i.e., physical) transmission at the lowest layer. These adjacent layers have a client/server relationship where a lower-level layer (server) provides the transport services to the higher-level layer (client). An example of client/server relationship occurs between the OCh and OMS layers in optical transport networks (OTN). It is important to observe that client/server relationship is not dependent on information flow directionality (uni or bi-directional). It only depends on network layer organization (technology and protocols).

Besides Partitioning and Layering, other important definitions are: Transport Processing Functions (TPFs) and Reference Points (RPs). The TPF are blocks which process information that pass through them by their input and output ports. There are two types of transport processing functions: Trail Termination Function (TTF) and Adaptation Function (AF). The RP represents a binding between input and output of different instances of TPF and other physical components. There are three types of RPs: AP (Access Point), CP (Connection Point) and TCP (Termination Connection Point).

An example of abstract transport network using the ITU-T G.805 visual language is presented in Figure 1.

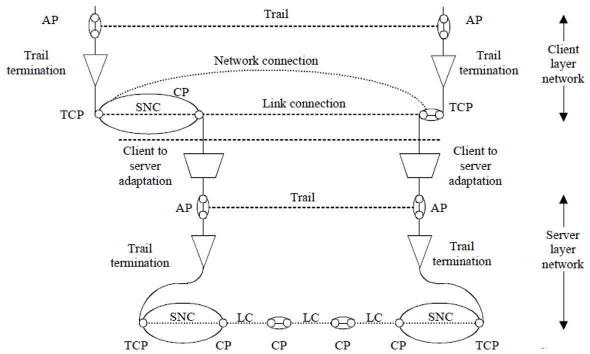

Figure 1- Example of Transport Network **[1]**

B. A Framework for Ontological Evaluation

As previously mentioned the framework proposed in [7] and employed here uses an Ontology-Based Conceptual Model of the domain as a reference model for evaluating a representation artifact for that domain. The idea is that this reference model stands for a canonical representation of that domain conceptualization.

The rationale behind that framework is based on a number of theoretical as well as experimental works, which demonstrate that stronger the match between a reference model and a representation artifact, the easier is to understand and reason with that representation. The easiest case is when we have a complete match, i.e., when these two entities are isomorphic [7]. The implication of this for the human agent who interprets the representation is that his interpretation correlates precisely and uniquely with an abstraction being represented. By contrast, where the correlation is not an isomorphism then there may potentially be a number of (unintended) different models which would match the interpretation.

The framework, thus, propose a systematic method for evaluating the level of homomorphism between the reference model and the representation artifact. In order for this mapping to be isomorphic, there are four different formal properties which this correlation must exhibit, namely: lucidity, soundness, laconicity and completeness. When these properties are absent in a mapping, four different patterns of problems arise. These are **Construct Overload**, **Construct Excess**, **Construct Redundancy** and **Incompleteness**. These patterns of problems are summarized and illustrated in figure 2 and are discussed in the sequel.

Construct Overload happens when a (interpretation) mapping from the representation to the reference model is not functional (in the set theoretical sense), i.e., when a construct in the representation stands for more than one domain concept. Construct overload is considered an undesirable property of a representation since it causes ambiguity and, hence, undermines clarity. When a construct overload exists, users have to bring additional knowledge not contained in the representation to understand the phenomenon which is being represented.

Construct Excess happens when a (interpretation) mapping from the representation to the reference model is not total (in the set theoretical sense), i.e., when there is a construct in the representation which lacks interpretation in terms of a domain concept. Construct Excess is an undesirable property for two reasons: firstly, because they add complexity to the representation without increasing its expressivity; secondly, because users tend to ascribe anyway an interpretation for that construct. However, since these interpretations are not accounted for in the representation system itself, there is no guarantee that the interpretation given to a construct by a reader of the model will coincide with one intended by the creator of that model [7].

Construct Redundancy happens when a (representation) mapping from the reference model to a representation is not functional, i.e., when a domain concept is represented by more than one representation artifact. Construct redundancy is known for undermining representation clarity. On one hand, it also adds complexity to the representation without increasing its expressivity. On the other hand, users tend to ascribe different (inconsistent and not-accounted-for) interpretations for the different representations [7].

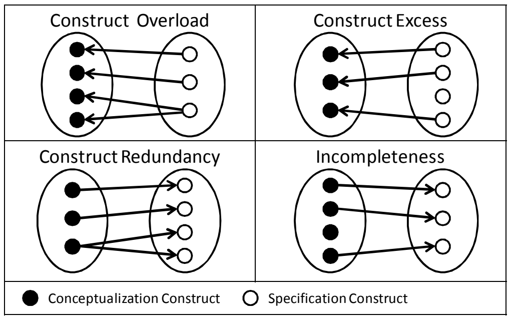

Figure 2 - Ontological deficiencies in a mapping from a canonical expression of a domain and a representation artifact. Based on **[4]**

Finally, *Construct Incompleteness* happens when a (representation) mapping from the reference model to the representation artifact is not total. In other words, a representation is said to be complete if every concept in a domain is covered by at least one modeling construct of the representation. *Completeness* at the language level is perhaps the most important property that should hold for a representation system. Representation incompleteness entails lack of expressivity, i.e., that there are phenomena in the considered domain (according to a domain conceptualization) that cannot be represented by the language. Because that expressivity is, nonetheless, necessary to express ideas of that domain, frequently, users of the language choose to overload an existing construct in order to represent the missing domain concept. This move, however, entails a construct overload, hence, undermining clarity [7].

III. An Ontological Analysis and Evaluation of the ITU-T Recommendation G.805

In this section, we use the framework discussed in the previous section to systematically evaluate the quality of the ITU-T Recommendation G.805 as a representation of its underlying domain. As well as identifying a number of ontological deficiencies in this representation artifact, we show fragments of the proposed reference model to illustrate possible solutions to the problems at hand. These fragments are depicted using an Ontologically Well-founded Conceptual Modeling language dubbed OntoUML [7]. OntoUML is an extension of the standard modeling language UML (the Unified Modeling Language – see http://www.uml.org). For instance in the model of figure 4, entity types are represented as boxes, while lines represent relationship types. Moreover, a black diamond represents a parthood (composition) relation with the diamond attached to the whole entity, and an arrow represents a generalization (supertyping) relationship with the arrowhead attached to the supertype. Furthermore, numbers shown adjacent to a relationship-end represents cardinality constraints and a term enclosed in guillemets (⟨⟨⟩⟩) inside a box indicates the ontological category of the entity types represented by that particular box.

A. End of recursion in Layer Networks as well as the distinction between Link and Link Connection

The ITU-T Recommendation G.805 divides the layer network in two different groups: the Path Layer Network (which is independent of technology) and the Transmission Media Layer Network (which is technology-dependent). The two types of layers share similarities (for example, they are defined by TTFs of equal types) as well as differences. One of the characteristics that set them apart is the fact that the path layer can be either client or server to another layer, while the transmission layer has no server layer, i.e., it is always a server, but never a client layer. The transmission layer is not supported by lower layer Trails or Network Connections, but by a link. The layered structure of a network can be seen in Figure 3 below.

In the G.805 Recommendation, Links are defined as topological components, i.e., they are abstract concepts to represent the topology of a layer network. In fact, this topological link corresponds to the topological view of Link Connections which are logical connections from a transportation view. A simplified modeling of the topological components can be seen in Figure 4.

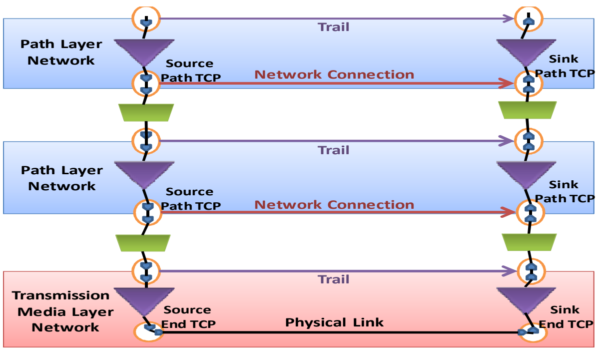

Figure 3 - Path and Transmission Media Layer composition

It can be viewed in the model of figure 4 that topological components are of the following types: Topological Layer Network, Access Group, Link and Subnetwork. A Layer Network is composed by TTFs, LCs and Matrixes. Its topological representation is composed of topological type components called here Layer Topological Components (AG, Link and Subnetwork). It is noteworthy that each one of the Layer Network components has a corresponding Layer Topological Component. That is, the latter represent objectified (reified) properties (qualities, aspects) of components that constitute the transport network components. Once the correspondence between these two viewpoints (i.e., transport and topological viewpoints) is formally established, depending on the level of abstraction required by a user application, an automatic transformation between concepts can be realized.

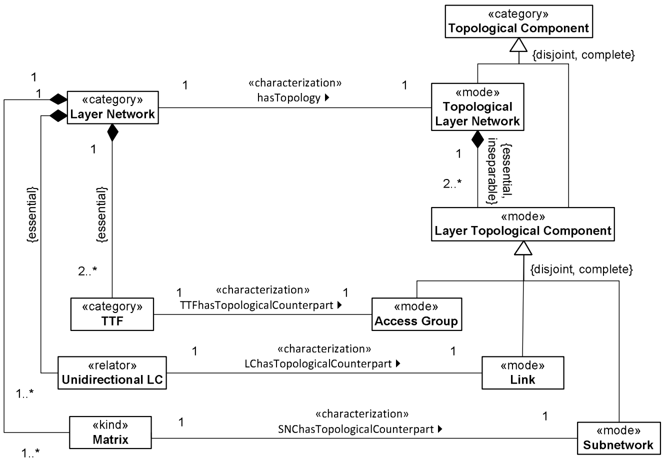

Figure 4 - Topological Components conceptual model

A very important information which is explicitly represented in the model of figure 4 (but which is completely absent in the G.805 specification) is the fact that entities such as Link and Subnetwork, on one side, are existentially (lifetime) dependent on entities such as Link Connection and Matrix, on the other. This is represented by the characterization relation in the model, which is one the lifetime dependence relations in OntoUML. As an example, we can then say that a Link is an aspect (a topological qualification) of a Link Connection and, thus, it can only exist if the Link Connection it qualifies exists. Once this semantic aspect is identified and properly represented in the reference model then it can be preserved in all implementations and products derived from this model.

Lifetime dependence has also been used in the construction of our reference model to identify the different ontological status of entities represented. For instance, the entity types stereotyped as ⟨⟨mode⟩⟩ and ⟨⟨relator⟩⟩ represent two different types of lifetime-dependent entities: the former represents intrinsic properties or aspects of certain individuals; the latter represent relational properties binding multiple individuals. In contrast, an entity type stereotype as ⟨⟨kind⟩⟩ represents an Object, i.e., an entity that is existentially independent which can exist by itself and of which other entities can depend upon.

Contrasting figure 4 with figure 5, one can notice that the transmission layer link (termed here **Physical Link**) cannot be considered equal to the other links described in the recommendation. As the models make explicit, these entity types belong to different ontological categories: while the Link is an existentially dependent intrinsic feature of an object (a *mode*, the physical link is a *kind*, persistent over time and with its own independent identity [7,9]; while the former represents , an LC representation in the topological view, the latter is a physical component of the network where, indeed, the data transmission takes place. Moreover, a Physical Link cannot be inferred from the existence of an LC (like other links) and it is not part of the network topological view. Finally, in Figure 5, it can also be seen that the Physical Link composes only the Transmission Media Layer Network and not the Path Layer Network.

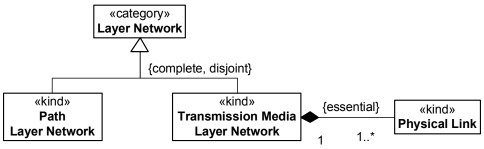

Figure 5 – Physical Link model

The lack of the Physical Link concept in the ITU-T Recommendation G.805 constitutes a case of incompleteness of this representation w.r.t. its subject domain, i.e., it is not the case that every concept in the underlying domain is covered by at least one concept in the specification.

B. Reference Points

The Reference Points (RPs) are defined in G.805 Recommendation as follows:

Reference points are formed by the binding between inputs and outputs of transport processing functions and/or transport entities. The allowable bindings and resultant specific types of reference points are shown in Table 1.

The first sentence of this definition indicates that Reference Points are formed by the connection between inputs and outputs of Transport Processing Functions (TPF) and/or Transport Entities. However, since Transport Entities do not define physical connections but represent the network information transfer capability, it is incorrect to assert that the connection of Transport Entities inputs or outputs with TPFs result in an RP. In fact, RPs are created by the connections that occur between the network physical components (e.g. TPF). Since RPs exists by the connection of TPF inputs and outputs, the beginning and end of Transport Entities can be defined from them, and not the contrary, as the recommendation claims. The validity of this conclusion can be argued for given the definition of Transport Entities in the recommendation:

The transport entities provide transparent information transfer between layer network reference points.

The second sentence of the Reference Points definition says that the allowable bindings and resultant specific types of reference points are found in a recommendation´s table. Table 1 below illustrates part of this table.

As previously mentioned, the table shows the creation of reference points from bindings between TPF and Transport Entities. The position defended here is that RP occurs by bindings of network physical components. This position clearly contradicts Table 1. In the sequel, for the sake of argument, we first considered the case of the Termination Connection Points and subsequently the case of the Connection Points.

TABLE 1 - ALLOWABLE BINDINGS AND RESULTING REFERENCE POINTS

Architectural Components		Reference Point
AF	TTF	AP
TTF	LC	TCP
TTF	SNC	TCP
LC	SNC	CP
LC	LC	CP
AF	AF	CP

AF: Adaptation Function
TTF: Trail Termination Function
LC: Link Connection
MC: Matrix Connection
SNC: Subnetwork Connection
AP: Access Point
TCP: Termination Connection Point
CP: Connection Point

1) Construct Overload in the TCP Definition

TCPs are defined as the result of bindings between Termination Trails (TTF) and Link Connections (LC) or Subnetwork Connections (SNC). These LC and SNC are network logical components, inferred from the RP, in a clear reversal of definitions – RPs are defined from Transport Entities that are defined by RPs. It is suggested in this work that TCPs are created by bindings of network physical components: for the case of Path Layers, for the source size, they occur between Source TTF outputs and Source AF inputs or by Source TTF outputs and matrix connections and are called, respectively, Path and Matrix TCPs; for the Transmission Media Layer case, TCPs are classified by the specific type End TCP and represents the binding of Source TTF outputs and a Physical Link input.

Table 2 below updates Table 1 according to the idea advocated in this work. In this table, RPs are formed by the binding of physical components, and not by bindings between physical components and transport components.

TABLE 2 - ALLOWABLE BINDINGS REVISITED

Architectural Components		Reference Point
AF	TTF	AP
TTF	AF	Path TCP
TTF	Physical Link	End TCP
TTF	Matrix	Matrix TCP
AF	AF	AF CP
AF	Matrix	Matrix CP

Using the ontological evaluation framework, we can show a case of construct overload present in the TCP definition: the recommendation (Table 1) defines TCP as a single concept when, in fact, it represents three different concepts (Path, End and Matrix TCP, as it can be seen in Table 2). Figure 6 illustrates the Path and End TCP for the case of a source network (Matrix TCP is not shown due to size limitation). In this figure, one can observe that both Source Path and End TCP are examples of *relators* (entities which are lifetime-dependent on multiple entities, thus, connecting them) [7]. This is the case since they indirectly mediate the relationships *TTF-AF source connection* and *TTF-End source connection, respectively.*

2) Construct Excess in the CP Definition

The CP case is a more complex one. According to the recommendation, as seen in Table 1, CP is created by three different bindings: AF with AF, LC with SNC, or LC with LC. This statement is in discordance with the position defended in this article, namely, that RPs are created by bindings of physical components (SNCs and LCs are transport representations, as mentioned before).

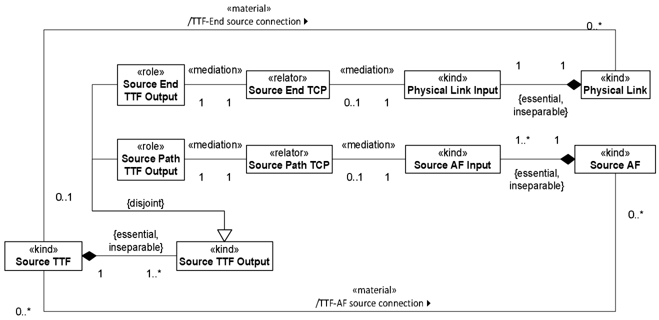

Figure 6 - Path and End TCP binding different physical components

Physically CPs represents the binding of a Sink AF output with a Source AF input or the binding of matrix with AF inputs and outputs (represented by the two last lines of Table 2), but at no time this fact is made explicit in the recommendation. Visual examples included in the recommendation are not clear about this fact, permitting the user´s interpretation, as can be seen in Figure 7. The left part of this figure shows a network section found in the recommendation, in which the existence of CPs is exemplified, but in this case, one cannot determine how the bindings that composed the CPs at hand are formed. The right part of the figure, a result of this work, displays the same network with greater detail, identifying physical bindings where the CP originates. The bindings are in full accordance with Table 2.

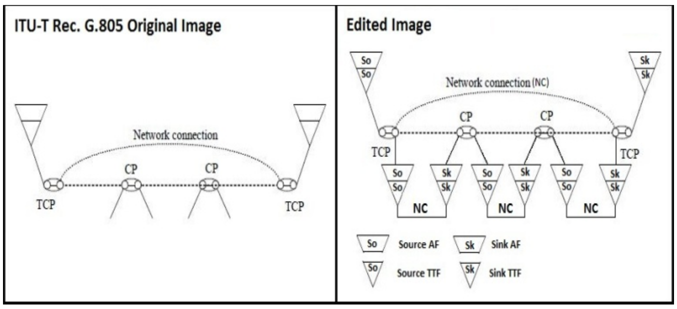

Figure 7 – Origin of Connection Points

The important point to be made here is that, in the G.805 specification, the CP concept uses a single construct, defined in three different ways, but it actually refers to two different entities. At first sight, this seems to constitute a case of construct redundancy (three definitions/representations for two domain concept). However, after a more careful analysis it becomes clear that the two additional configurations for a CP (represented by lines 4 and 5 in Table 1) cannot really occur in reality. Thus, these two representations do not have an interpretation in terms of a domain concept, i.e. a case of construct excess.

In fact, other contributions of the ontological evaluation here applied could not be presented due to space limitation. Incompleteness of concepts such as the transport Layer Network, presented in Figure 4, and of a Physical Matrix are some of them. Also, a construct redundancy was found for the Matrix Connection and Subnetwork Connection concepts.

IV. CONCLUSIONS

This paper shows the application of an ontology-based framework to systematically evaluate a number of properties of a domain representation artifact. In particular, it uses an ontologically well-founded reference model that stands for a canonical representation of the domain underlying ITU-T Recommendation G.805 (i.e., the domain of transport networks) to assess the current specification of the standard.

As demonstrated by the case study reported here, the use of ontology-based technologies such as an ontological conceptual modeling of a domain underlying a specification, as well an ontology-based evaluation framework can significantly help to identify deficiencies in this specification. In the case presented here, by using these technologies, we have been able to illustrate (as well as to provide solutions) to problems of incompleteness, construct overload and construct excess found in ITU-T Recommendation G.805. Since this recommendation is the basis for many others in the area of transport networks, it is essential that these problems are identified and corrected, so that their propagation to other recommendations (as well as to products derived from them) can be avoided.

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REFERENCES

[1] ITU-T, "Recommendation ITU-T G.805: Generic functional architecture of transport networks," Telecommunication Standardization Sector of ITU, International Telecommunication Union (ITU), March 2000.

[2] Renata S. S. Guizzardi and Giancarlo Guizzardi, "Applying the UFO Ontology to Design an Agent-oriented Engineering Language," *14th East-European Conference on Advances in Databases and Information Systems (ADBIS 2010)*, 2010.

[3] Giancarlo Guizzardi and Gerd Wagner, "Towards Ontological Foundations for Agent Modelling Concepts Using the Unified Fundational Ontology (UFO)," *Agent-Oriented Information Systems (AOIS), selected revised papersof the Sixth International Bi-Conference Workshop on Agent-Oriented Information Systems.*, 2005.

[4] Peter Fettke and Peter Loobs, "Ontological Analysis of Reference Models," in *Business Systems Analysis with Ontologies*. Hershey: Idea Group Publishing, 2005, pp. 56-81.

[5] G. Guizzardi, M. Lopes, F. Baião, and R. Falbo, "On the importance of truly ontological representation languages," *International Journal of Information Systems Modelling and Design (IJISMD)*, 2010.

[6] Bernardo Gonçalves, Giancarlo Guizzardi, and José G. Pereira Filho, "Using an ECG reference ontology for semantic interoperability of ECG data," *Journal of Biomedical Informatics*, 2010.

[7] Giancarlo Guizzardi, *Ontological Foundations for Structural Conceptual Models*. Enschede, The Netherlands: Telematica Instituut Fundamental Research Series, 2005.

[8] Pedro Paulo F. Barcelos, Maxwell E. Monteiro, Ricardo Simões, Marcelo E. V. Segatto, and Anilton S. Garcia, "OOTN - An Ontology Proposal for Optical Transport Networks," *International Congress on Ultra Modern Telecommunications and Control Systems (ICUMT)*, pp. 1-7, 2009.

[9] Maxwell E. Monteiro, Anilton S. Garcia, Pedro Paulo F.Barcelos, and Giancarlo Guizzardi, "Ontology Based Model For The ITU-T Recommendation G.805: Towards The Self-management Of Transport Networks," *International journal of computer science & information Technology (IJCSIT)*, vol. 2, no. Number 2, pp. 155-170, April 2010.