Specifying the Technology Viewpoint for a Corporate Spatial Data Infrastructure using ICA's Formal Model

Rubens Moraes Torres[1], Italo Lopes Oliveira[2], Jugurta Lisboa-Filho[1],
Carlos Alberto Moura[3] and Alexander Gonçalves Silva[3]

[1]*Departamento de Informática, Universidade Federal de Viçosa, Viçosa, MG, Brazil*
[2]*Departamento de Informática e Estatística – Universidade Federal de Santa Catarina, Florianópolis, SC, Brazil*
[3]*Companhia Energética de Minas Gerais (Cemig), Belo Horizonte, MG, Brazil,*

Keywords: Spatial Data Infrastructure, RM-ODP, Technology Viewpoint, ICA Model, SDI-Cemig.

Abstract: In the quest to create a formal model for the development of Spatial Data Infrastructure (SDI), the International Cartographic Association (ICA) has proposed a model based on the RM-ODP framework to describe SDIs regardless of the implementation and technology. The RM-ODP framework comprises five viewpoints. The ICA has proposed the specification of the Enterprise, Computation, and Information viewpoints while the Engineering and Technology viewpoints are yet to be specified. The *Companhia Energética de Minas Gerais* (Minas Gerais Power Company - Cemig) develops an SDI, called SDI-Cemig, aiming to facilitate the discovery, sharing, and use of geospatial data among its employees, partner companies, and consumers. This study presents the specification of the technologies that comprise the components of SDI-Cemig using the Technology viewpoint integrated to ICA's formal model.

1 INTRODUCTION

Users work with a Spatial Data Infrastructure (SDI) in order to recover or perform operations with geospatial data (e.g., converting geographic coordinate systems), which enable spatial-temporal analyses and the use of decision-making support mechanisms (Jhummarwala et al., 2014).

Based on the SDI concept, several initiatives both in the public and private sectors have been developed for the use, sharing, and recovery of geospatial data aiming to create an environment in which people can cooperate with each other and interact to reach political and administrative goals in an optimized manner (Alencar et al., 2013). According to Harvey et al. (2012), SDIs improve the sharing and use of geospatial services and helps different users of a given community.

The *Companhia Energética de Minas Gerais* (Minas Gerais Power Company – Cemig) is a company acting in the power sector in Brazil, currently a corporation comprehending over 200 businesses, that delves in power generation, transmission, and distribution, besides gas distribution and communications networks (Cemig, 2016).

Cemig develops an SDI called SDI-Cemig aiming to help its employees, partner companies, and clients share and discover geospatial data. The company has created a project with the participation of other governmental organizations in order to create this SDI. The research and development project "Geoportal Cemig – SDI-Based Corporate GIS" is the result of a partnership between Cemig and the *Fundação de Amparo à Pesquisa do Estado de Minas Gerais* (Research Support Foundation of the State of Minas Gerais - Fapemig). One of the goals of this project consists in creating a method to develop corporate SDIs (Alves et al., 2016).

For SDI specification and development, the International Cartographic Association (ICA) proposes a model based on the Reference Model for Open Distributed Processing (RM-ODP) framework. ICA's model for SDI specification describes three of the five viewpoints in the RM-ODP framework: Enterprise, Information (Hjelmager et al., 2008), and Computation (Cooper et al., 2013). The other two viewpoints of the framework, Engineering and Technology, have not been described in ICA's model and were left open with the caveat of being dependent on the implementation to be used (Cooper et al., 2011).

Torres, R., Oliveira, I., Lisboa-Filho, J., Moura, C. and Silva, A.
Specifying the Technology Viewpoint for a Corporate Spatial Data Infrastructure using ICA's Formal Model.
DOI: 10.5220/0006311503330340
In *Proceedings of the 19th International Conference on Enterprise Information Systems (ICEIS 2017) - Volume 2*, pages 333-340
ISBN: 978-989-758-248-6

Other researchers have extended the Enterprise viewpoint, specializing the description of the actors and policies of an SDI (Cooper et al., 2011; Béjar et al., 2012; Oliveira and Lisboa-Filho, 2015). According to Oliveira et al. (2016a), ICA's formal model can be used to specify corporate SDIs. Torres et al. (2016) developed a modeling on the engineering viewpoint for a corporate SDI based on the RM-ODP model.

According to Putman (2000), the Technology viewpoint enables specifying an architecture of technologies to be employed in the implementation of hardware and software according to the features described in the other four viewpoints.

This way, this paper presents the specification of the Technology viewpoint for SDI-Cemig based on ICA's adapted formal model for SDI. The paper is structured as follows. Section 2 describes ICA's formal SDI model. Section 3 presents the specification of the Technology viewpoint for the case study of SDI-Cemig. Section 4 presents the final considerations and possible future works.

2 ICA'S FORMAL MODEL FOR SDI SPECIFICATION

RM-ODP is a framework for the specification of heterogeneous distributed systems that provides distribution, interoperability, portability, and platform and technology independence (Farooqui et al., 1995). The framework results from a partnership among the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), and the Telecommunication Standardization Sector (Raymond, 1995).

The RM-ODP framework is made up of five viewpoints, each one representing an architectural viewpoint of the system (Egyhazy, 2004). Since each viewpoint does not represent an isolated part of the system, it describes a different way of observing the same system (Putman, 2000). By using these viewpoints, the model is specified in five smaller models, where each viewpoint deals with specific relevant issues for different users (Linington et al., 2011).

Figure 1 illustrates the five viewpoints of the RM-ODP model. The definitions proposed by Linington et al. (2011) and Putman (2000) on each viewpoint are summarized below:

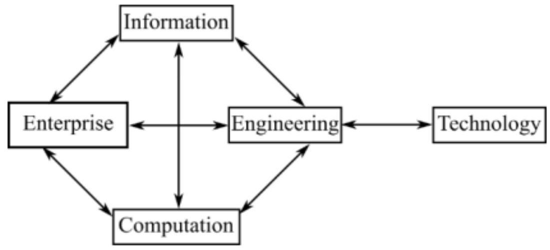

Figure 1: RM-ODP framework viewpoints – Adapted from Hjelmager et al. (2008).

- The Enterprise viewpoint is responsible for the scope and policies for project composition, the step in which the system requirements will be defined.
- The Information viewpoint works with semantics of the information and its processing, describing the structures and types of data used in the system.
- The Computation viewpoint is related to functionalities, whose viewpoint of the system is a division of several functionalities. In this view, there is concern in describing the functionalities provided by the system in terms of objects and those functionalities are broken down into functional objects with interaction through their own interfaces.
- The Engineering viewpoint is built observing mechanisms and features needed to support interactions among the system functionalities described in the Computation viewpoint. There is concern in defining logical units for processing and information, focusing on its logical distribution, as well as its communication in terms of communication channels. Moreover, the Engineering viewpoint focuses on the distribution among components and channels for its communication.
- The Technology viewpoint is related to the needs of the system regarding the technologies required. It describes the technologies for information processing, functionalities, and visualization.

In Hjelmager et al. (2008), the ICA proposed using the RM-ODP model as a reference to design and create an SDI. By using it, one can model the data semantics, policies (Hjelmager et al., 2008), actors (Hjelmager, 2008; Cooper et al., 2011), objects, and functionalities required in an SDI (Cooper et al., 2013). The model has the advantage of being highly independent from implementation and technology (Hjelmager et al., 2008). Organizations at different levels (e.g., national, regional, local, corporate) can use the same modeling when implementing their SDIs and one organization may choose to use a specific set of technologies while another may implement the project with a different set (Putman, 2000).

This study approaches the Technology viewpoint of SDI-Cemig. The definitions detailed in the Enterprise and Information viewpoints can be found in Oliveira and Lisboa-Filho (2015) and Oliveira et al. (2016a), the Computation viewpoint was presented in Oliveira et al. (2016b), and the Engineering viewpoint was presented in Torres et al. (2016).

2.1 Technology Viewpoint

According to Putman (2000), the Technology viewpoint provides a view in terms of software and hardware in the construction of the system, minimum technology requirements needed, as well as evolution of its useful life. This viewpoint represents a concrete view of the components created in the other viewpoints of the RM-ODP framework aiming to describe the components that will receive the products and technologies for the implementation, besides allowing the components to be verified for adequacy (Raymond, 1995).

The RM-ODP model provides structures to be used in its composition during creation. The ISO/IEC 10746-3:2009(E) (2010) norm describes the following structures to be used when creating the Technology viewpoint: Technological Object; Implementation Standard, and IXIT (Implementation eXtra Information for Testing).

The technological specification is based on the use of Technological Objects, components that abstract a piece of hardware or software to be used in the system implementation (Linington et al., 2011).

According to Wnuk et al. (2014), the compatibility among distinct technologies is constantly advancing. Companies that develop hardware and software tend to create their products so that they are increasingly more compatible with technologies from other manufacturers for them to be able to work along in a harmonious and functional manner. However, some technologies are still incompatible among themselves. Given this possible incompatibility, schemas relating the set of components and technologies used to verify the system's compatibility and performance must be specified (Linington et al., 2011). In order to cover this demand, the RM-ODP model recommends the definition of Project Implementation Standards, a diagram in which the technologies employed are specified related to their respective Technological Objects (ISO/IEC 10746-3:2009(E), 2010).

Technological Objects may be followed by basic information to be verified in its implementation and test. In order to add this content, the RM-ODP framework defines the IXIT (Implementation eXtra Information for Testing) concept. IXIT contains extra information that guides the project implementation to verify its basic functioning needs. Its creation consists in text elements attached to the Technological Objects to be specified (Putman, 2000).

3 SPECIFICATION OF THE TECHNOLOGY VIEWPOINT: SDI-Cemig CASE STUDY

This section presents the specification of the Technology viewpoint of SDI-Cemig. The elements of this viewpoint were specified according to the components documented in the viewpoints Enterprise (Oliveira et al., 2016b), Computation (Oliveira et al., 2016a) and Engineering (Torres et al., 2016).

The diagram created consists in nine Technological Objects representing firewalls, networks, servers, and the system user as illustrated in Figure 2. Its creation is based on the requirements described by the previous viewpoints of ICA's model for the SDI-Cemig model in Oliveira et al. (2016b), Oliveira et al. (2016a), and Torres et al. (2016) and by Cemig's Technical Report N.002/2016 (Alves et al., 2016).

The element *RemoteSystem* represents a system user who wishes to access SDI-Cemig. To that end, the user has two interfaces: A web browser and services for communication with traditional softwares for Geographic Information System (GIS) handling. There are two Technological Objects representing firewalls for access control to the system. The first element, *ExternalFirewall*, consists in a protection against external breaches and unauthorized access, controlling all connections among the servers in the *CemigLAN* network with computers in external *WAN* networks. The second firewall, *InternalFirewall*, consists in extra protection for the access to information for the component *DataServer*, a server containing geographic information and managed by a database.

Its creation complies with a norm by Cemig according to which there must be extra protection for the access to the server storing geographic data (Alves et al., 2016).

The other Technological Objects represent four servers responsible for several features in the system. They are made up of the following components: *PortalCemigServer*, *CataloguerServer*, *DataServer*,

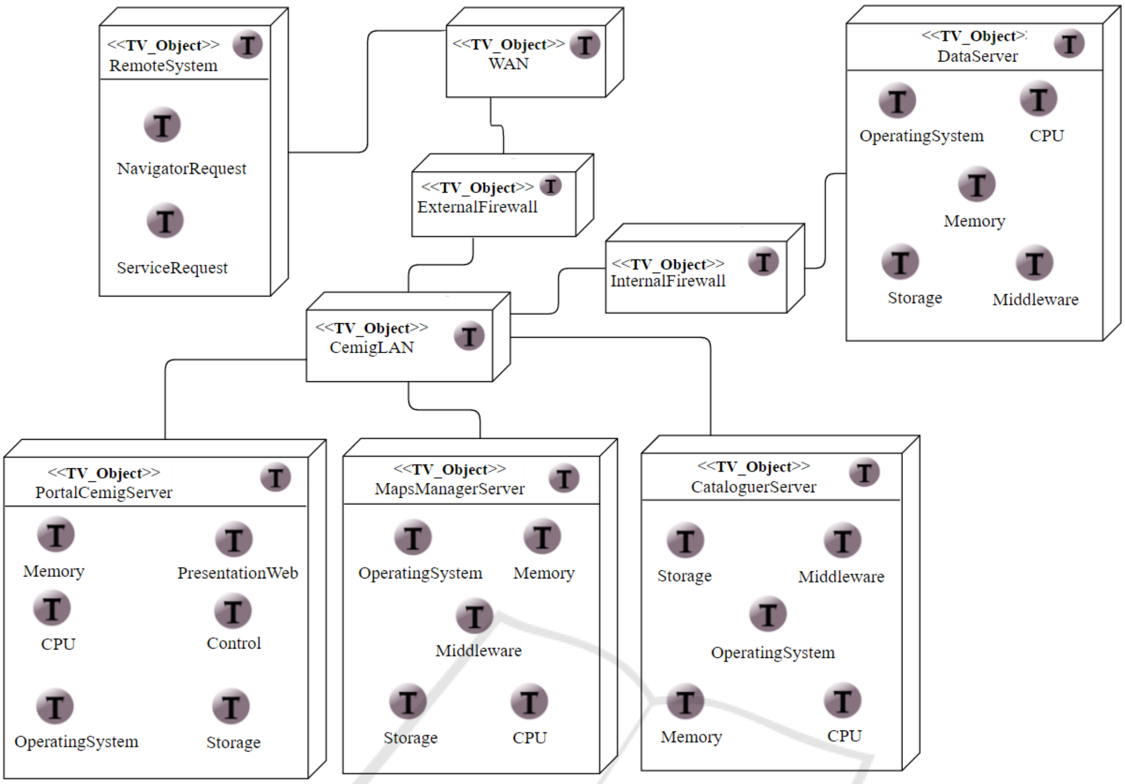

Figure 2: Technological Objects of SDI-Cemig.

and *MapsManagerServer*.

The Technological Object *DataServer* represents a server where geographic information is stored. It stores information in a database capable of storing and managing spatial data.

MapsManagerServer is a server responsible for generating a graphical visualization of data from information provided by the object *DataServer*. It must reply to calls from web browsers and web services.

CataloguerServer consists in a server that provides a catalog with geographic information available for the user in the database. The information must be provided along with their metadata, which follow the Brazilian Geospatial Metadata Profile (MGB) (CONCAR, 2009).

Finally, the object *PortalCemigServer* consists in a server in charge of providing a web interface for the object *RemoteSystem*, whose interface allows accessing the following system functionalities for the Engineering viewpoint (Torres et al., 2016): *PortraitSDICemigOps*, *DataSDICemigOps*, and *CatalogSDICemigOps*. In order to meet those needs, the server communicates with the objects *MapsManagerServer* for map generation, *CataloguerServer* to obtain a data catalog, and *DataServer* to obtain geographic data from the geographic information database.

Fonseca (2016) analyzed and compared several softwares and technologies available on the market to be used in SDI implementations. That study proposed several tools to work with components in an SDI, such as a map server, data server, and information catalog.

PortalCemigServer is responsible for the browsing interface using technologies that may be implemented on a website (e.g., OpenLayers, AngularJS). To that end, the technologies chosen are familiar to the company and preferred by it (Alves et al., 2016).

For the construction of internal components of the servers *MapsManagerServer*, *CataloguerServer*, and *DataServer*, which have specialized purposes, the technologies chosen were suggested by Fonseca (2016) and comply with CEMIG. Figure 3 illustrates the use of those technologies linked to their respective Technological Objects.

The *PortalCemigServer* server has the components *PresentationWeb* and *Control*. The component *PresentationWeb* represents the system visualization layer and the use of the AngularJS[1] framework was proposed for its construction. For the component *Control*, the Ruby on Rails[2] framework was designated.

For the servers *MapsManagerServer*, *CataloguerServer*, and *DataServer*, the softwares MapServer[3], GeoNetwork[4], and PostgreSQL[5], respectively, were designated.

Those softwares, according to Fonseca (2016), are well adequated as components when building SDIs. Aiming to contemplate the need to replicate data in the Engineering viewpoint (Torres, 2016), the server *DataServer* uses the technology Redundant Array of Independent Disks (RAID) for the component *Storage* (Ellis et al., 1996).

The component *RemoteSystem* has the element NavigatorRequest, which is represented by a browser that uses HyperText Markup Language 5 (HTML5) to access the system via the web.

The components *CemigLAN*, *WAN*, *ExternalFirewall*, and *InternalFirewall* do not have extra specification for being established standards representing networks and firewalls.

Figure 4 represents the IXIT diagram of the SDI-Cemig model. The diagram contains additional information that must be observed in the technological implementation process. The operational system versions are defined by Cemig and do not restrict migrating to another system as long as based on a Linux environment.

Hardware specifications represent the minimum hardware that must be used in the project and are based on the minimum specifications defined by each respective technology provider. The software versions defined are the current versions and serve as guidance, with no restriction against the use of a more recent version. However, the use of new versions requires the verification of continued compatibility and interoperability among the technologies employed. New system functionalities can be included with the creation of new technological components provided that those components have a communication interface in common with the rest of the system and have a service-oriented communication architecture.

The IXIT diagram describes the main communication rules that must be verified in the implementation among components. The *RemoteSystem* must have software compatible with the Web Map Service (WMS) and Web Feature Service (WFS) standards for the use of different web services, whether from other SDIs or not, and HTML5 for the browser interface. *CataloguerServer*, with the use of GeoNetwork, must be able to access the GeoServer software and the *PortalCemigServer* component through a Representational State Transfer (REST) interface (Fielding, 2000). *MapsManagerServer* must allow access through the WMS and WMF standards. *PortalCemigServer* and *DataServer* must communicate based on REST.

The Technology viewpoint (Figure 3) implements the components described in terms of functionalities by the Computation viewpoint of SDI-Cemig (Oliveira et al., 2016a). The elements of the Technology viewpoint are listed below with their corresponding components in the Computation viewpoint:

- The component *RemoteSystem* corresponds to the components *User*, *Provider*, *Operational Body*, and *Cataloguer*;
- *PortalCemigServer* contemplates the user interfaces proposed in the package *User_Interfaces*;
- The server *MapsManagerServer* serves *Portrayal_SDI-Cemig*, responsible for map visualization;
- *CataloguerServer* serves *Metadata_Management* and *Catalog_Management* for information cataloging along with their corresponding metadata;
- *DataServer contemplates the objects Data_SDI-Cemig, Data_Vectors_Management, and Data_Rasters_Management, responsible for the management of information in the database.*

[1] https://angularjs.org/

[2] http://rubyonrails.org/

[3] http://www.mapserver.org/

[4] http://geonetwork-opensource.org/

[5] http://www.postgresql.org/

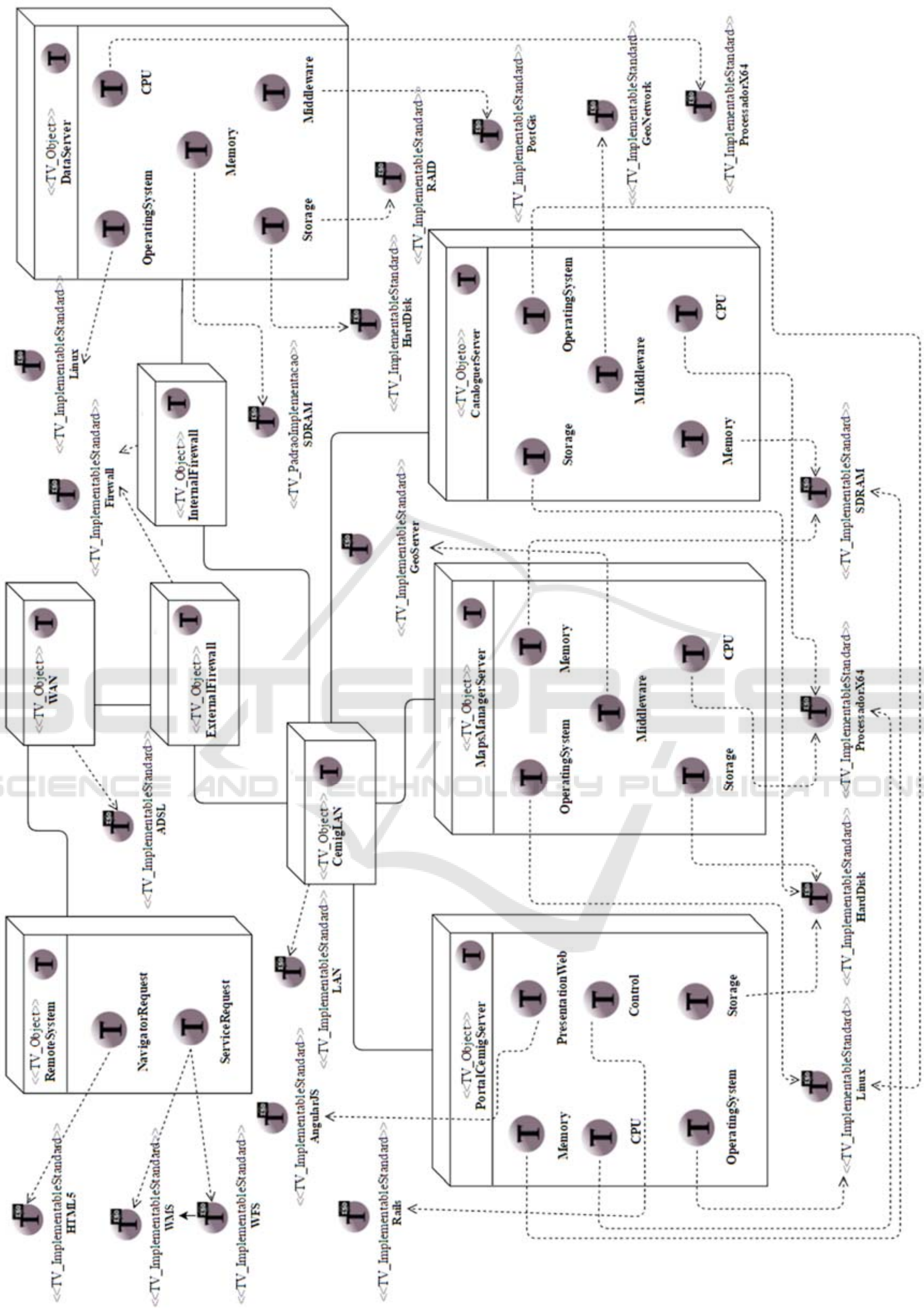

Figure 3: Standards for SDI-Cemig implementation.

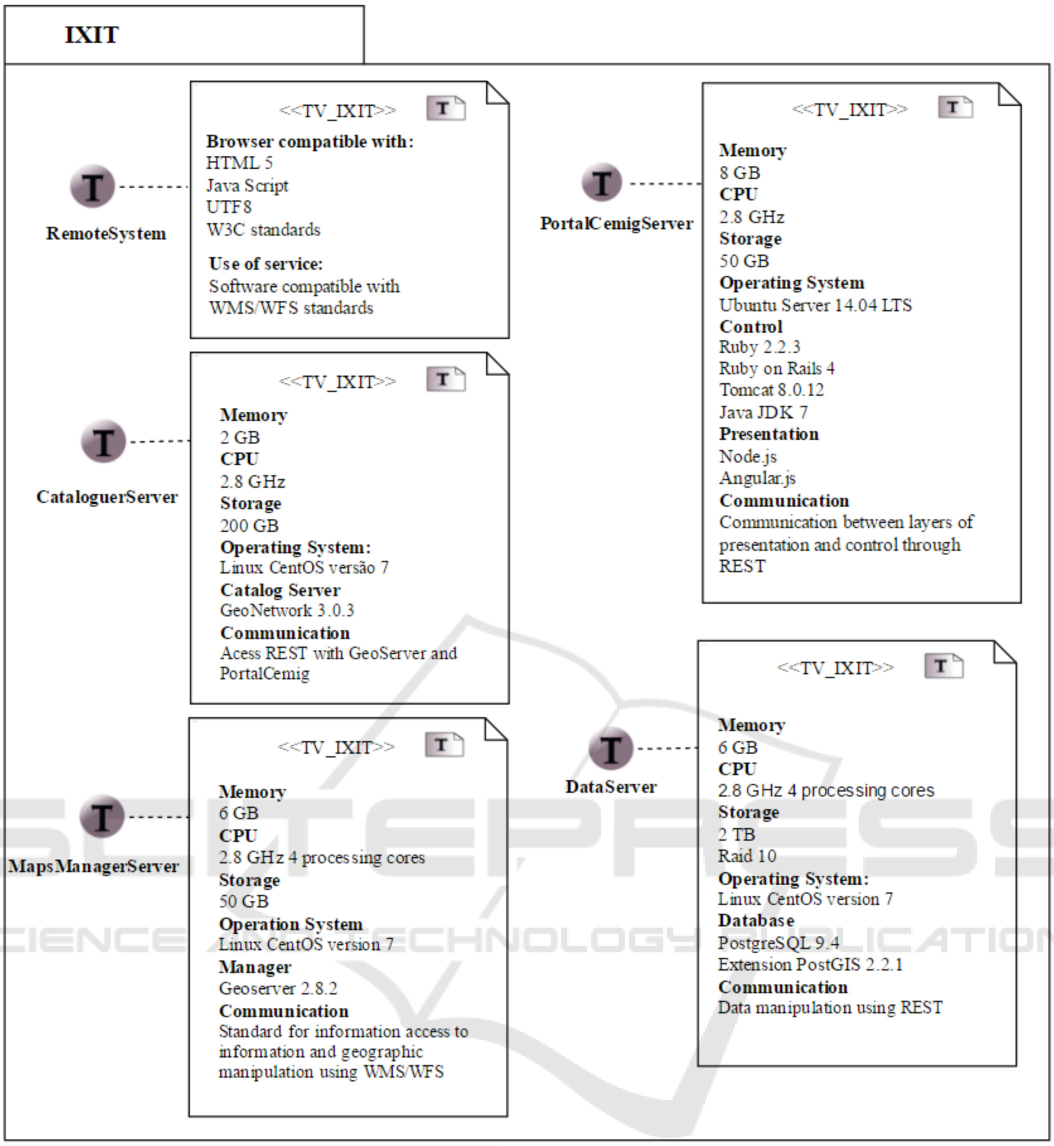

Figure 4: IXIT diagram for SDI-Cemig.

4 FINAL CONSIDERATIONS

With the specification of the fifth viewpoint of ICA's model, SDI-Cemig has a model contemplating all five viewpoints of the RM-ODP framework, which allows the model to be consulted as a whole. In other words, the specification of all viewpoints provides an overall, specialized view of SDI-Cemig.

The Technology viewpoint comprises Technological Objects representing from physical components to functionalities, where they are organized independently and isolated from each other. Its communication is performed through a service-oriented architecture in which a Technological Object makes a request to another component through a common communication interface.

Although the viewpoint created defines technologies to be used in the implementation of a corporation, the specification of the Technology viewpoint for SDI-Cemig suggests that a similar specification could be used in other SDIs not only corporate and related to the power sector, but also at different levels (e.g., regional, national, local). In case changes are desired, such as switching technologies, the model made up of modules allows for those changes as long as the new technology meets the requirements described in the viewpoint. The use of independent modules makes it easier to include new functionalities in the system since new components may be added with no significant changes to the project.

As future works, it would be important to apply ICA's formal model onto broader SDIs such as at the regional and national levels.

ACKNOWLEDGEMENTS

This research project was partially funded by Fapemig and CAPES, along with Cemig.

REFERENCES

Alencar, C. M. S. d., Santos, P. L. V. A. d., et al., 2013. Acesso À Informação Geográfica: Reflexões Sobre A Importância das Infraestruturas de Dados Espaciais nas Políticas Públicas. *Liinc em Revista*, p. 488-501.

Alves, A., Liboa-Filho, J., Oliveira, I., 2016. *Plano de Implantação da Infraestrutura de Dados Espaciais SDI-Cemig*. Relatório Técnico do PPGCC, Universidade Federal de Viçosa.

Béjar, R., Latre, M. Á., Nogueras-Iso, J., Muro-Medrano, P. R., Zarazaga-Soria, F. J., 2012. An RM-ODP enterprise view for spatial data infrastructures. *Computer Standards & Interfaces*, v. 34, n.2, p. 263-272.

Cemig, 2016. Mémoria Cemig. Available at: http:// www.cemig.com.br/pt-br/a_cemig/Nossa_Histor ia/Paginas/default.aspx.

CONCAR – Comissão Nacional de Cartografia, 2009. Perfil de Metadados Geoespaciais do Brasil (Perfil MGB). Available at: http://www.concar.ibge.gov.br/ arquivo/perfil_mgb_final_v1_homologado.pdf.

Cooper, A. K., Moellering, H., Hjelmager, J., et al., 2013. A spatial data infrastructure model from the computational viewpoint. *Int. Journal Geographical Information Science*, v. 27, n. 6, p. 1133-1151.

Cooper, A. K., Rapant, P., Hjelmager, J., et al., 2011. Extending the formal model of a spatial data infrastructure to include volunteered geographical information. *25th Cartographic Conference (ICC).*

Egyhazy C., Mukherji R., 2004. Interoperability Architecture Using RM-ODP. *Communications of ACM*, v .47, n. 2.

Ellis, R. A., Lubbers, C. E., Malan, S. J., Rivera, P., Snyder, S., Thiel, D. W., Wells, R. B., 1996. Method and apparatus for preserving data integrity in a multiple disk raid organized storage system. *U.S. Patent No. 5,504,858*. Washington, DC.

Farooqui, K., Logrippo, L., De Meer, J., 1995. The ISO reference model for open distributed processing: and introduction. *Computer Networks and ISDN Systems*, v. 27, n. 8, p. 1215-1229.

Fielding, R. T., 2000. Architectural styles and the design of network-based software architectures. PhD thesis, University of California, Irvine.

Fonseca, F. J. B., Pereira, L. V. S., Lisboa-Filho, J., 2016. Comparando Sistemas Webgis de Exibição e Processamento de Informação Geográfica no Contexto da INDE. Conferencia Ibérica de Sistemas y Tecnologías de Informacion (CISTI), v. 1, p. 250-255.

Harvey, F., Iwaniak, A., Coetzee, S., Cooper, A., K., 2012. SDI past, present and future: a review and status assessment. *Spatially Enabling Government, Industry and Citizens*.

Hjelmager, J., Moellering, H., Cooper, A. K., et al., 2008. An initial formal model for spatial data infrastructure. *International Journal of Geographic Information Science*, v. 22, n. 11-12, p. 1295-1309.

ISO/IEC 10746-3:2009(E), 2010. Information Technology Open Distributed Processing Reference Model: Architecture. *Standard, International Organization for Standardization / International Electrotechnical Commission*, Switzerland.

Jhummarwala, A., Potdar, M., Chauhan, P., 2014. Parallel and Distributed Gis for Processing Geo-Data: an Overview. *International Journal of Computer Applications*, v. 106, n. 16.

Linington, P. F., Milosevic, Z., Tanaka, A., Vallecilo, A., 2011. *Building Enterprise Systems with ODP: An Introduction to Open Distributed Processing*. CRC Press.

Oliveira, I. L., Lisboa-Filho, J., Moura, C. A., Silva, A. G., 2016a. Specifying the computation viewpoints for a corporate spatial data infrastructure using ICA's formal model. *International Conference on Computational Science and Its Applications*, p. 275–289.

Oliveira, I. L., Lisboa-Filho, J., Moura, C. A., Silva, A. G., 2016b. Specifying the enterprise and Information viewpoints for a corporate spatial data Infrastructure using ICA's formal model. *Proceedings of the 18th International Conference on Enterprise Information Systems*, v. 1, p. 271–282.

Oliveira, I. L., Lisboa-Filho, J., 2015. A spatial data infrastructure review – sorting the actors and policies from enterprise viewpoint. *Proceedings of the 17th International Conference on Enterprise Information Systems*, v. 17, p. 287-294.

Putman, J. R., 2000. *Open Distribution Software Architecture Using RM-ODP*. Prentice Hall PTR.

Raymond, K., 1995. Reference Model for Open Distributed Processing (RM-ODP): Introduction. *Open Distributed Processing*, p. 3-14.

Torres, R. M. T., Oliveira, I. L., Lisboa-Filho, J., Moura, C. A., Silva, A. G., 2016. Specifying the engineering perspective of ICA's formal model in a corporate spatial data infrastructure. The 9th Int. Conference on Advanced Geographic Information Systems, Applications, and Services (GeoProcessing 2017).

Wnuk, K., Runeson, P., Lantz, M., Weijden, O., 2014. Bridges and Barriers to Hardware-Dependent Software Ecosystem Participation – A Case Study. *Information and Software Technology*, v. 56, n. 11, p. 1493-1507.