A Methodology for Emerging Telecommunication Technology Experiments Based on Virtual Environment and AI Techniques

Ilham BENYAHIA
Department of Computing and Engineering at Université du Québec en Outaouais (UQO)
101, rue Saint-Jean-Bosco, pièce B-2036, C.P. 1250, Succursale Hull
Gatineau, (Québec) CANADA J8X 3X7

ABSTRACT

Advanced telecommunications technologies innovations evolve quickly and are often considered as a main component of critical and emerging applications such as Intelligent Transportation Systems (ITS) and Smart Grid (energy systems). The need for rapid deployment of these technologies requires their testing to assess their performance and if necessary seek appropriate configurations that optimize the QoS (Quality of Service) of associated applications. Existing simulation tools for testing these technologies remain limited when it comes to appraise their innovations involving additional knowledge. We present in this paper a methodology to design and develop a tool for training and experimentation of technologies innovations such as telecommunication. Our approach is focused on the integration of virtual reality concepts based on object oriented modeling and 3D techniques for realistic scenarios experimentation. We also consider artificial intelligence techniques such as inference mechanisms to enable the integration of new knowledge of the technologies to be tested and their management.

General Terms

Advanced simulation; Technologies innovations, Complex applications, Training, Knowledge Management.

Indexing Terms

3D Object oriented modeling, virtual reality environment, knowledge management, virtual scientific laboratory, intelligent tutorial, telecommunication advanced technologies, knowledge extraction, machine learning, information technology.

Academic Discipline and Sub-Disciplines

Computers; Telecommunications technologies innovations.

Subject Classification

Object modeling classification; Telecommincation technologies classification.

1. INTRODUCTION

Innovations in information technologies such as telecommunications are more and more frequent while critical and emerging applications such as Intelligent Transport Systems (ITS) [1] and Smart Grids require their rapid deployment [2]. Such deployment needs require performance testing of these technologies operating in environments that represent critical applications in a realistic way. Experimental results are important to define the suitable configurations prior to the real-life operations and deployments of these technologies.

In addition to testing the recent innovations of these technologies, it is important to acquire the new knowledge to define suitable models and scenarios for experiments. Regarding telecommunications, today's networks performance experimentations are often based on simulators integrating classical models of operation of these networks such as ns-2, Opnet, etc. [3]. However, these simulators hardly support extensions and require significant development efforts in order to add new components and behaviors depicting the new innovations of these technologies.

Another problem related to the use of existing simulators to test new technologies for the rapid deployment required by emerging applications is related to the limits to define realistic scenarios and contexts of their uses. Existing simulators models are predefined and cannot represent realistically the characteristics and dynamics of real-world applications. For example, for telecommunication ad-hoc networks traffic and mobility cannot represent realistic mobility models for vehicular networks in the field ITS applications.

The environments modeled according to virtual reality concepts will represent accurate environment structures and mobility. Based on virtual reality contributions, we consider here the virtual laboratories of scientific experiments as an alternative to experiment information technology techniques [4].

Despite the benefits of technology models to test the behavior of some technologies such as fiber optic model, virtual labs for scientific experiments are also limited and will not be suitable for testing innovations of these technologies to be deployed for critical applications since they are not reusable and are developed for a specific technology.

Testing the technologies innovations through virtual scientific laboratories requires rapid integration of new knowledge regularly. The development efforts necessary for most existing virtual scientific laboratories to integrate new knowledge related to the innovations will not meet the needs of rapid deployment of these technologies since it requires a multidisciplinary team working for a development that can take a long time.

We propose in this paper a methodology for the design and development of a new tool for advanced technologies experiments. The main goal is to evaluate their performance and make decisions related to their applications in the context of emerging and critical applications.

This paper is structured as follows. In Section 2, we present a background on scientific experiments based on the virtual reality environments, Section 3 presents a methodology of designing a new environment for experimenting technologies innovations for rapid deployment for critical applications. Section 4 presents two case studies emphasizing the role of object oriented modeling and artificial intelligence techniques such as inferences. Section 5 provides a conclusion and future directions.

2. A BACKGROUND ON VIRTUAL ENVIRONMENT FOR SCIENTIFIC EXPERIMENTS

We present in this section a state of the art on scientific experimentation based on virtual laboratories.

Virtual laboratories are designed to make scientific experiments in a virtual environment characterized by a computer-generated, three-dimensional representation of a setting in which users of the technology perceive themselves to be in, within which interaction takes place. Among the best known scientific laboratories we consider the biology and biochemistry, physics and astronomy.

Several features are required to develop virtual scientific laboratories such as computer aided design, 3D modeling and development, analysis, storage and transmission of data.

The environment defined in [5] is for editing chemical features. Another laboratory exercise focused on chromatography is described in [6]. The VirtLab [7] is based on simulations and drills for dynamic models of chemical elements. The VirtLab is also engaged in research in the design and development of Grid technologies that help solve large-scale calculations on intensive science applications in the field of molecular biology

The laboratory ChemLab [6] originated from academic work in computer simulation and software design at McMaster University. It has continued to be developed with extensive input from educators interested in the possible application of computer simulations for classroom and distance learning.

Molecular modeling which is initially intended only for theorists is becoming a laboratory tool in itself. The introduction of graphical user interfaces, making the use of computer codes more user-friendly, cannot alone explain the amazing growth in recent years. More powerful computer models and more refined work are needed for such a development.

Simulated experiments in physics take place in the virtual space manipulation, based on a 2D representation. The LVP (Laboratory VirtualPhysics) does not contain the basic pedagogical scenario. The experiments of these laboratories are relatively complex and are not those that would normally be offered to first-time users of LVP. [8]

Other laboratories such as (E = mc2) [9] can experiment several areas. This lab is based on experiments and enables physics applets, chemistry and astronomy, etc. Using applets allows animation to visualize the behavior of physical phenomena which depend on several parameters.

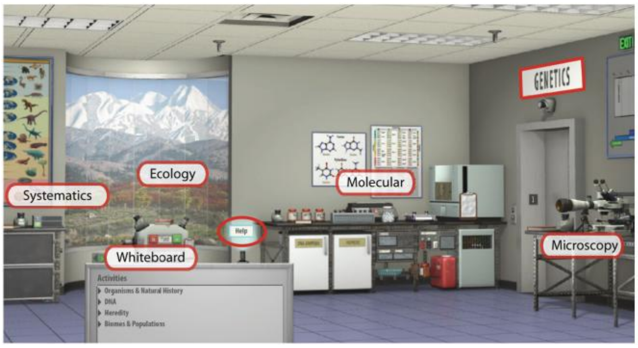

Figure 1: Virtual Experiment Laboratory [7]

In [10], the virtual lab enables a hands-on approach to understand the fiber optic technology, both for sensing and communications. Different characteristics related to fiber behavior can be tested and learned.

However, these experiments are carried under laboratory conditions and the performance results for different scenarios are limited. For example, the optical fiber is environmentally sensitive and that for example the border air-glass will affect the errors rate. Then if the tests are carried out within a given environment, then the consequences of the fiber calibration or configurations remain limited to this environment.

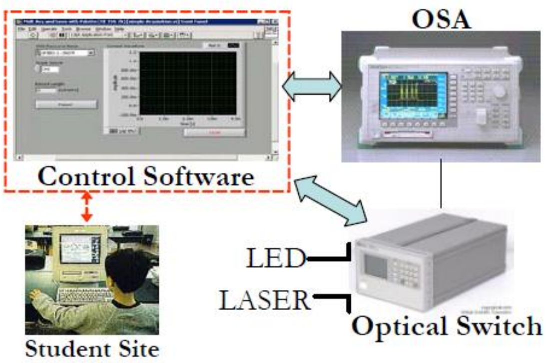

Figure 2: Laboratory for Fiber optic Experiments [10]

Testing wireless and ad-hoc networks to define their reliability is another example underlining the importance of testing technologies in realistic environments associated to the critical applications. For this technology, there is an impact of the environment geometry and mobility on signals quality due to the risk of interferences.

Given the importance of testing the technologies in virtual environments with the possibility to integrate new components rapidly, the components of these virtual environments must be defined in a way that will enable dynamic integrations such as the use of object oriented technique. Thus, the integration of the innovations for the technologies by creating new knowledge will also require a minimum of development effort due to the modularity and reusable components. Due to object technology properties such as reusability and modularity, virtual reality based on 3D object technology has more advantages than other languages for virtual reality such as extensibility and viability.

Because of the previous requirements to allow experiments for new innovations based on realistic scenarios, there is a need to define a proper environment to ensure the utility of these technologies configuration and calibration resulting from their experiments.

3. A METHODOLOGY FOR TELECOMMUNICATION TECHNOLOGIES EXPERIMENTS FOR EMERGING APPLICATIONS

In this section, we define numerous phases to be considered for experiments and training of the technologies to be deployed in the critical applications to study. The main components defined in Figure 3 are also considered in these phases. Figure 3 illustrate architecture components of a suitable environment for technologies experiments. Our architecture is based on MVC model (Model View Controller). It integrates a user interface, a data base to store 3D objects and a set of processing techniques including IA (Artificial Intelligence) for experiments and inferences on the 3D objects.

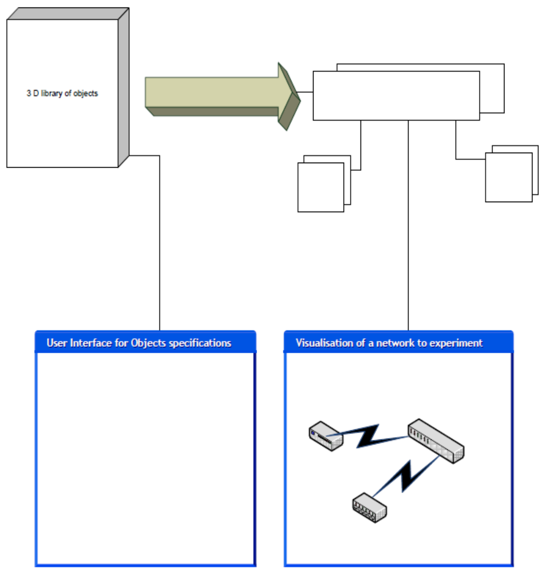

Figure 3: Architecture Components of Virtual Environment for Experiments

3.1 Experimental phases of technology innovations

The components of the virtual environment will be modeled and developed according to the 3D object technology to define realistic experimental scenarios. Defining realistic interactions between the components of the technology and those related to the future deployment of this technology will enhance the accuracy of these experimental results.

The main phases for the new experimental environment defined in this paper are summarized as follows:

1. Identification of the technology components from the associated library as illustrated in Figure 3.
2. Identification of the virtual components associated with the application scenarios of experiments.
3. Construction of the technology and the application models and their validation from the technical documentation associated with each library of components (Figure 3).
4. Establishment of the interactions between the components of the two models according to the inference rules defining the behavior of the technology components.
5. Triggering of inference rules associated with the components interactions with the initialization operating parameters as defined for these components.
6. Data collection for their observation and analysis.
7. Iteration of the procedure from the phase 2.

As an illustration of an environment to model in order to test a technology, we consider connected-vehicles technology enabled with inter-vehicular communication [11] in the context of STI. Experimental scenarios will be defined according to road network characteristics that would include components like tunnels, high rise buildings that may impact the quality of transmission. An example of behavior to test will be represented by protocols for routing of packets transmitted between these vehicles.

3.2 New knowledge integration phase

Conducting experiments on emerging technologies innovations requires the integration of new knowledge and their management within the library of components presented in Figure 3. New knowledge will be integrated through an interface which is part of this new experimental environment. Thus, for the technology considered, experts will extract new knowledge for its integration within existing technology bases. The specification knowledge interface will be associated with the current technology and its related application such as ITS, Smart Grid, etc.

The AI component presented in the experimental architecture (Figure 3) will be used for new knowledge integration and validation. An inference mechanism will detect contradictions of new knowledge and past one. It will also generate potential additional knowledge by combining the whole technology knowledge (new and basic). Knowledge of innovated technologies extension phases are defined as follows:

1. Extraction of new knowledge of new innovations.
2. Formulation of new knowledge according to the interface template and associated key-words (technology and application domain for the current context).
3. Activation of AI techniques for the new knowledge integration and validation.
4. Update the technical documentation for the additional components for use in the next experiments for the technology learning.

Users of such technologies must understand their functions before integrating them in their experiment model. Despite the association of technical documentation, training of new knowledge of such technologies can become a hard task according to the background of populations interested by the experiments of these technologies.

Thus, to learn the new concepts or to experience the technologies, a suitable learning is necessary. Our approach to deal with this particular need is to define adaptive pedagogic techniques according to the background of the technologies deployment users. The training strategies will satisfy the learning objectives according to the user background.

4. A CASE STUDY BASED ON OBJECT MODELING

In this section we present two case studies illustrating learning and experimentation in the domain of telecom networks. The first case study illustrates an object approach where we have the basic components of a telecom network, and in the second case study we present an interface for testing the configuration process for a commutation function of ATM technology.

We present in this section two case studies on learning and experimentation in the field of telecommunication networks. The first case illustrates components of a telecommunications network and the ATM (Asynchronous Transfer Mode) technology based on an object oriented approach and the second case provides an interface to experience the process of configuring an ATM switch [12].

4.1 Acquiring knowledge on a network component

Figure 4 illustrates telecommunication network components knowledge to acquire prior to any experiment. Each component is represented by an object and is defined by its technical specifications that appear on the interface which will show up on the technology to experiment with objects.

Extensions of the basic information on each component will be defined from the interface template in order to capture new knowledge related to the architecture or behavior of each component.

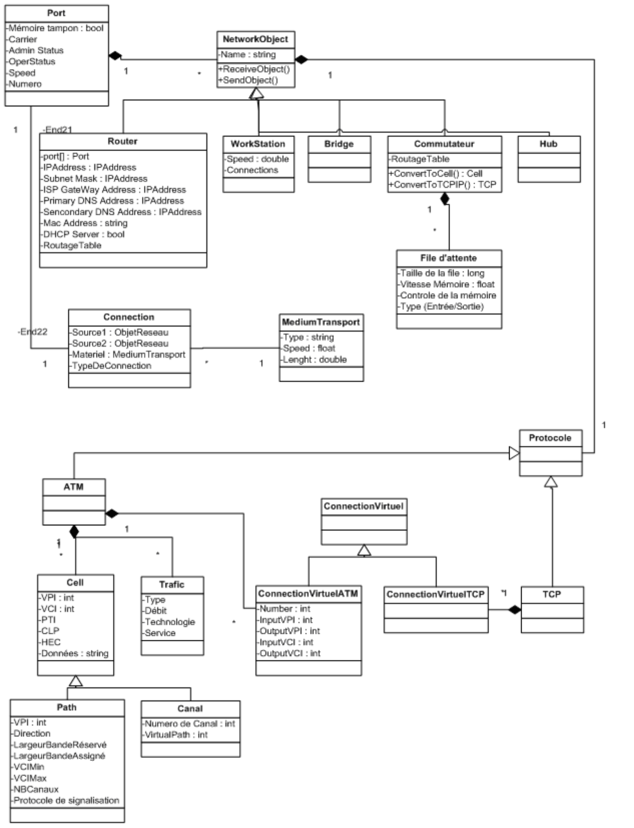

Figure 4: Architecture components of a network system Training

4.2 Configuration of ATM Switch

The second case developed and illustrated in Figure 5 consists of configuring an ATM switch according to the real life ATM switch configuration process. The object model that defines the illustrated switch object is based on the technical specifications of a Marconi ATM switch [13].

The ongoing work on the experiment environment for technologies that require rapid deployment of their continuous innovations is related to ITS and especially on vehicular networks. The road infrastructure represents the main environment that interacts with the vehicular network. Its modeling is based on concepts of 3D object technology. Representing accurately the geometry of the road infrastructure such as the presence of tunnel, high rise buildings, etc. identifies the impact of the interactions between vehicles network model and its environment (road infrastructure).

In this context, Experiments will be related to innovations of the routing protocols to identify algorithms that optimize time responses of vehicular communications in critical ITS application context for road safety defined by collision avoidance.

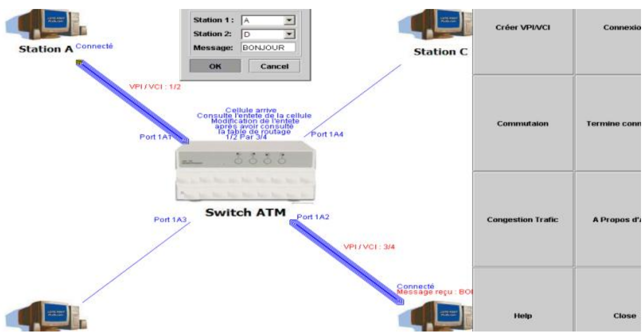

Figure 5: Experiments for ATM Switch Configuration

5. CONCLUSION AND FUTURE DIRECTIONS

This paper is related to technologies experiencing continuous innovations and that are expected to be deployed rapidly in the context of critical applications. Facing the limits of current experimental environments, we define a methodology for the design of a new environment for experimentation.

The experimental environment designed this way will be used for advanced technologies learning and experimentations considering realistic scenarios associated with the critical applications that will adopt these technologies.

The realistic representation of the technologies operation contexts is based on object 3D modeling techniques as well as concepts of virtual reality. Artificial intelligence techniques such as inference mechanisms are considered to integrate and validate new knowledge gained from the technologies innovations. A compliant template-based interface is also defined for knowledge integration with the experiment environment architecture.

The definition of a library of components related to vehicular networks is in progress to define a specific experiment environment according to the methodology presented in this paper. The experiments will concern the study of the performance of new routing protocols based on our research results [14].

A generic level of an experimentation environment will be developed according to our methodology. We will also define techniques that will adapt the experiment environment according to the technologies and critical applications that need to deploy these technologies.

6. REFERENCES

[1] Dar, K, Bakhouya, M., Gaber, J., Wack, M., Lorenz, P., Wireless Communication Technologies for ITS applications, IEEE Communication Magazine, Vol. 48, pp. 156-162, 2010.

[2] Ghassemi, A., Bavarian, S., Lampe, L., Cognitive Radio for Smart Grid Communications, First IEEE International Conference on Smart Grid Communications (SmartGridComm), pp. 297 – 302, 2010.

[3] Imran, M., Said, A.M., Hasbulllah, H., A survey of simulators, emulators and testbeds for wireless sensor networks, International Symposium in Information Technology, Vol. 2, pp. 897 - 902, 2010.

[4] Trindade, J., Fiolhais, C., Almeida, L., ` Science learning in virtual environments: a descriptive study, British Journal of Educational Technology, Vol. 33, Issue 4, pp. 471-488, 2002.

[5] http://www.jce.divched.org/

[6] Stone, DC, Using Virtual Laboratory Exercise. *Journal of Chemical Education*, 84 (9), 2007.

[7] http://www.virtlab.com/main.aspx

[8] http://www.dl.ket.org/physicslabs/labs/

[9] emc2: http://www.emc-sq.com/emc2lab.html

[10] Franzl, R., Gurkan, D., Benhaddou, D., Mickelson, A., E-Learning Laboratories for Optical Circuits Separation of Imperfections in Technology and Teaching Methodologies, Proceedings of The 2006 IJME - INTERTECH Conference, 9 pp, 2006.

[11] Khaled, Y., Ducourtthial, B., and Shawky, M., IEEE 802.11 performances for inter-vehicle communication networks`, IEEE 65th Vehicular Technology Conference, Vol. 5, pp. 2925-2929, 2005.

[12] Gupta, B. K., Lal, M., Sharma, S. C., Improving Quality of Service Parameters in Wireless Asynchronous Transfer Mode Network, 2nd International Conference on Mobile Technology, Applications and Systems, pp. 1-8, 2005.

[13] Marconi, ATM Switch Configuration Manual, Marconi Plc, 1999.

[14] Benyahia, I., A Survey of Ant Colony Optimization Algorithms for Telecommunication Networks, International Journal on Applied Metaheuristic Computing, Vol. 3, pp. 15, 2012.

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Ilham Benyahia biography

Ilham Benyahia is professor at the Department of Computing and Engineering at Université du Québec en Outaouais (UQO), Canada since 1997. She held a PhD in Computer Science in 1993 from Université Pierre et Marie Curie (UPMC) in Paris. She then held a postdoctoral position with the Center for Research on Transportation, University of Montreal. From 1995 to 1997, she has been a Researcher with the Research Institute of Hydro-Québec. Her research interests include architectures and frameworks for complex applications and artificial intelligence (AI) to solve complex problems in telecommunications and transportation related to Intelligent Transportation Systems (ITS). Her research in AI is based on metaheuristics (genetic algorithms, ant colony optimisation algorithms...) for autonomous networks. She is especially interested by information management and communications of vehicular networks for road safety.

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