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IEEE Canadian Review

La revue canadienne de l'IEEE

Power Milestone

Manitoba's HVDC System Honoured

- Passivity as a Framework for Design and Analysis of Networked Systems
- Adaptive Routing Algorithms for All-Optical Networks
- Ingénierie des exigences - L'outil de support GenSpec
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Editorial / *Éditorial*

Eric Holdrinet SMIEEE, Co-Rédacteur en chef / Managing Co-Editor, Consul et délégué commercial, Consulat général du Canada à Los Angeles

Chers collègues et membres du IEEE Canada, c'est avec plaisir et respect pour le travail accompli par mes prédécesseurs à la barre de la Revue canadienne de l'IEEE que j'entame l'édition d'une nouvelle série en tant que Co-Rédacteur en chef de la Revue. Ce rôle sera partagé par Mr. Terry Malkinson, SMIEEE, membre élu du sénat de l'Université de Calgary, éditeur et contributeur expérimenté de plusieurs revues du IEEE dont le *IEEE-USA News and Views* et le *IEEE EMS Engineering Management.*

Ensemble, avec l'aide aussi du Directeur de la publicité (et ex-Rédacteur en chef) M. Vijay Sood ainsi que des Editeurs Associés MM. Samuel Pierre, Camille-Alain Rabbath, Alain Zarka et Habib Hamam, nous comptons vous présenter des nouvelles pertinentes à votre profession et des articles de haut niveau d'intérêt pour la communauté canadienne.

Le présent numéro renferme des articles portant sur des sujets éminement canadiens: la célébration par IEEE du Système de transmission HVDC de la Rivière Nelson au Manitoba, deux articles sur les télécommunications (via fil cuivré pour un tutoriel DSL, via fibre optique pour un article sur le routage dynamique), le deuxième d'une série sur l'Ingénierie des exigences (rédigé dans un contexte de génie électrique), et un article sur le contrôle dynamique des système en réseau - écrit par nos chercheurs à la Défense Nationale et collaborateurs universitaires.

Nous voulons des reporters: contactez nous pour une expérience enrichissante en communications et journalisme technique. Ecrivez des articles sur ce qui se passe au Canada, dans votre insitution, companies, communauté. Soyez lu par environ 15 000 de vos pairs.

Ayant passé le jalon du 50e numéro, notre équipe éditoriale réaffirme les buts de la *Revue* qui sont de produire du contenu que nos membres veulent lire , qui reflète les réalités de notre profession d'un océan à l'autre, et complémente les grandes revues techniques de l'IEEE tel le *Journal canadien de génie électrique et informatique* (abonnez-vous en renouvelant votre adhésion à l'IEEE !)

Dear colleagues and members of IEEE Canada, it is with both pleasure and respect for the work performed by my predecessors at the helm of the *IEEE Canadian Review* that I inaugurate a new series as Managing Co-Editor. This role will be shared by Mr. Terry Malkinson, SMIEEE, elected member of the University of Calgary Senate, Editor and experienced contributor to many IEEE magazines like *USA News and Views* and *IEEE EMS Engineering Management*.

Together, with the help of Advertisement Manager (and past Editor) Mr. Vijay Sood, as well as Associate Editors MM Samuel Pierre, Camille-Alain Rabbath, Alain Zarka and Habib Hamam, we will continue to present news that is relevant to your profession and articles of high-level interest for the Canadian community.

This Issue contains articles about subjects that are wholly Canadian: The recognition by IEEE of pioneering works at the Nelson River HVDC Transmission System in Manitoba, two articles on telecommunications (via copper fiber for a DSL Tutorial, via optical fiber for an article on dynamic routing), the second of a series of articles about Requirements Engineering (developed in a Power Engineering context), and an article on networked systems dynamic control — written by our research colleagues at National Defence Labs and their academic collaborators.

We want IEEE reporters: please contact us for a rewarding experience in technical journalism and communications. Write high-level articles about what is happening in Canada, your University, your Company, your Community. Get read by about 15, 000 of your peers.

As we have now passed the 50th Issue Milestone, our editorial team reaffirms the *Review*'s goals to produce content our members want to read**,** that reflect realities of our profession from Coast to Coast, and that complements the great technical journals that IEEE publishes such as the *Canadian Journal of Electrical and Computer Engineering* (please subscribe when renewing your IEEE membership !)

Dr Ferial El-Hawary elected
IEEE Canada Director '08 -'09 (Dir.-Elect '06-'07)

Dr. Ferial El-Hawary P. Eng., F MTS, F EIC, F IEEE received the M.Sc. in Electrical Engineering from the University of Alberta (1971) and the Ph.D. in Oceans Engineering from Memorial University of Newfoundland (1981). She is President of BH Engineering Systems Ltd., Halifax, Nova-Scotia, Canada.

She has published widely in IEEE refereed Journals on OCEANS Applications. She is Editor-in-Chief of "The OCEANS Engineering Handbook" and Associate Editor of the IEEE Oceanic Engineering Journal in Applications of Computational Intelligence, Advanced Underwater Signal Processing, Kalman Filtering Techniques, and Data Fusion.

Cover picture / *Photo de couverture*

The Limestone hydroelectric generating station (cover photo), together with the Kettle and Long Spruce stations, form the backbone of Manitoba's hydroelectric generating capacity, producing between the three of them a total of 3750 MW. Key to utilizing the potential of these northern sites was the development in the early '70s of a low-loss transmission system, realized with the Nelson River HVDC Transmission System. *(See article on Page 5).*

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IEEE Canadian Review General Information

The ***IEEE Canadian Review*** is published 3 times/year as follows: Winter (to appear in April); Spring/Summer (to appear in August); Fall (to appear in December). Its principal objective is to project an image of the Canadian electrical, electronics, communications and computer engineering professions and their associated academic and business communities to:

(i) Canadian members of IEEE;
(ii) Canadian members of the profession and community who are non-members of IEEE;
(iii) The associated Canadian academic (i.e. universities, colleges, secondary schools), government and business communities.

To ensure that the ***IEEE Canadian Review*** has the desired breadth and depth, editors are responsible for screening articles submitted according to the following general themes:

1- National Affairs	4- Education	7- Computers
2- International Affairs	5- Power	8 - Electronics
3- Industry	6- Communications	

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The circulation of the ***IEEE Canadian Review*** is the entire membership of IEEE Canada, representing over 12,000 subscribers.

Information for Authors

Authors are invited to contribute submissions in electronic form to the ***IEEE Canadian Review***. Please contact one of the editors. Responsibility for the content rests upon the authors and not the IEEE, or its members.

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Canadian Newslog / Coupures de presse Canadienne

Newslog Editor

Rédacteur des Coupures de presse

Alexandre Abecassis is a patent agent trainee in Montreal at Ogilvy Renault, Lawyers and Patent and Trade-mark Agents.

Alexandre Abecassis travaille à Montréal chez Ogilvy Renault, Avocats et agents de brevets et de marques de commerce, comme agent de brevets en formation.

Send any news clippings you would like to contribute via e-mail to alexandre.abecassis@ieee.org

Veuillez faire parvenir les coupures de presse proposées par e-mail à alexandre.abecassis@ieee.org

OTTAWA, ON, May 31, 2005. XINK Laboratories has announced the first on-press manufacture of functional UHF RFID transponder label. The antenna of the RFID transponder label was printed using XINK silver UHF antenna ink and the resulting four-color adhesive RFID label real over 14 feet.

VANCOUVER, BC, Oct. 13, 2005. Nicer Canada has announced the completion of the BC's Civic Election Campaign Call center. In the project, a large VoIP gateway was installed to provide more than 96 phone lines to handle large call centre operations. The VoIP gateway enables the providing of features such as fax through email, remote extension, inter-office calls for multiple locations, telephone conference, interactive voice response system, etc.

MONTREAL, QC, Oct. 31, 2005. Ubisoft Canada, a large video game producer, has launched its Ubisoft Campus which is a training center offering programs developed to cover competencies required in the production of video games. A scholarship program has also been developed in order to encourage students to pursue a career in the video game industry.

OTTAWA, ON, Oct. 27, 2005. 3,000 bar code scanners have been supplied by Metrologic Instruments to PG Elections who will be using them in the Canadian electoral process. Each voter, equipped with a bar coded voter identification card will go to the polls, have their card scanned using the scanner and then make their choice of leaders.

OTTAWA, ON, Oct. 24, 2005. Dinmar has announced that the Ottawa Hospital in Ontario has completed the first stage of a broad-scale implementation of the company's Java(TM)-based electronic health record platform. The platform enables over 6000 clinicians to access instantly patient lists and intuitive summaries along with detailed results and configurable views. Care providers also benefit from a wide variety of automated clinical decision support assistants, which streamline workflow and improve care quality.

MISSISSAUGA, ON, Oct. 3, 2005. Certicom has announced that nCipher has licensed Certicom's Intellectual Property portfolio to meet customer demand for elliptic curve cryptography (ECC) and also to meet requirements from the National Security Agency (NSA) for securing classified and unclassified government communications. The agreement allows nCipher to use ECC and other related Certicom patents as the public-key security technology in its hardware security modules and software solutions.

MONTREAL, QC, Sep. 21, 2005. The Université of Montréal and Ubisoft have signed an agreement for the joint development of research and training projects in the field of game design. Their primary collaboration will be on designing a graduate program to be offered on the Ubisoft campus, which will include a range of research activities directly linked to game design.

OTTAWA, ON, Sep. 8, 2005. Protus IP solutions has launched an interactive voice messaging solution that includes a new survey and polling feature designed for companies who require immediate feedback within business operations. Organization can now send telephone surveys to key contacts and expect an immediate response, along with detailed, real-time reports.

MONTREAL, QC, Aug. 30, 2005. Electronic Arts has announced a $2.6M training program that will provide its growing workforce of game makers in Montreal with the technical and creative skills they need to stay on the cutting-edge as they develop the next-generation of interactive entertainment. The curriculum will feature courses in: performance technology, graphics, engineering as well as project and people management.

MARKHAM, ON, Sep. 21, 2005. A new RFID center will be built and will act as a focal point for Canadian industry RFID discussions. It will provide not only educational capability but also a product testing facility. The center will focus on the retail, produce and consumer packaged good industries and demonstrates how RFID can enable a more accurate and cost effective way of implementing food traceability of frozen, fresh and dry food.

MONTREAL, QC, Aug. 31, 2005. CAE has signed a 10-year agreement with UK-based Virgin Atlantic Airways to provide training for pilots of the carrier's entire fleet of Airbus A340-600 and Boeing 747-400 aircraft. The total contract value may vary between $60M and $92M over 10 years depending on options.

MONTREAL, QC, May 30, 2005. Nstein Technologies has won the "Excellence OCTAS", the highest honour awarded by the Federation de l'Informatique du Quebec (FIQ), at the OCTAS 2005 Gala, as well as the "Technology Innovation OCTAS" for the early warning and monitoring solution derived from its Global Intelligent Information Management technology platform.

TORONTO, ON, May 18, 2005. University de Sherbrooke has selected DELL servers to power two new high-performance computing clusters (HPCC) used for scientific research in areas such as astrophysics, computational chemistry, bi-engineering, fluid dynamics, data mining, temperature superconductivity, nanoelectronics, pharmaceutical development and weather and climate forecasting. The supercomputer will have a theoretical performance of 8.3 trillion operations per second (TeraFLOPS).

MONTREAL, QC, Oct. 25, 2005. Bell Canada has announced that its IP telephony service is available for customers in the Greater Montreal Area. The service is already offered in Toronto. It will be possible to keep an existing phone number with the new service.

CALGARY, AB, Oct. 5, 2005. Telus has announced the launch of a wireless field ticketing solution designed for the oil and gas industry that allows companies to electronically capture crucial operational status and billing information from the field.

OTTAWA, ON, Aug. 26, 2005. Canarie, Canada's research and education network organization and Rogers Telecom announced a multi-million dollar contract whereby Rogers will provide a wide range of network services to support the CA(*) net 4 network. The CA(*) net 4 network is Canada's national research and innovation network.

Director's Report

When the members of Region 7 lent me the Presidency of IEEE Canada I laid out a course of action on what I would do over the next two years. The time has quickly passed and in my last article for the Canadian Review I find myself looking back at what I was able to accomplish. Also, IEEE Canada is faced with some new challenges and I want to briefly discuss those.

Probably the most important thing that was accomplished was the new governance structure. This is now in place and with the Tampa meeting the Operations Manual for Region 7 has been presented and approved. IEEE Canada's revised Bylaws were approved at the June RAB meeting. The new structure allows the ExCom to oversee all activities in Region 7 and when you open a door, you expose some opportunities. More on this later.

On the finance side, we put in place two important committees, Audit and Investment. The Audit Committee met in Saskatoon during the Spring Meeting and delivered its report to the IEEE Canada Board. Their recommendations have been accepted and are now incorporated into our operating procedures. An Investment Committee that reported in Tampa is examining how we protect our assets and how we access our surplus funds for the good of IEEE Canada.

I wanted to develop a Power System Seminar that I would be able to offer to Sections when I visited. That has been done and over the last two years it has been presented to six Sections in Canada, Association of Professional Engineers Geologist and Geophysicists of Alberta and Region 5. I have visited 12 Sections and helped celebrate significant anniversaries in some. By year's end I will have participated in two IEEE Milestone events, the Nelson River HVDC in Winnipeg and the 735 kV transmission in Quebec.

The addition of a third meeting concurrent with the students has allowed the ExCom to interface with the students. Members of the ExCom were called on to make presentations to the SAC meeting. When I visited Sections I tried to find time to address the student branches. Two of the Power System Seminars were coordinated by the student branches.

Telus has very generously established a prize for a student competition. The first contest was held this year with the finals held in Vancouver preceding the student and ExCom meetings. Lakehead University team captured first prize and on Saturday night they demonstrated their award winning project at the conclusion of the joint dinner for the students and ExCom. The agreement between Telus and IEEE Canada will run for five years, and we can expect more competition over the next four years.

Thanks to hard work by the Quebec Section, Sections Congress 2008 will be held in Quebec City in 2008. In August I visited Quebec City along with staff from Piscataway for a site visit of the facilities for Sections Congress. The local chair, Paul Fortier, is assembling his team and I'm sure IEEE Canada will once again show the IEEE world a good party.

I want to conclude by bringing two issues to the attention of IEEE Canada members. They are also opportunities for us to enhance and strengthen IEEE Canada.

The first is engaging Sections. The IEEE Canada Board and especially its ExCom exists to assist the Sections in exposing IEEE to others. Part of IEEE's mission statement is "enabling members' careers". The ExCom depends on the Sections for the delivery of IEEE products and services and in this regard I'm talking about technical matters. While the ExCom and the IEEE Canada Board can develop and facilitate these programs we depend on the local Sections to deliver the goods! In our fast changing world, we must be doing this.

The second issue is finances. Past IEEE Canada Treasurers were foresighted enough to hedge our funds against the declining Canadian dollar. This had a good and a bad side. The bad side was it cost our members more each year as the Canadian dollar declined against its American counterpart. The "good" was that IEEE Canada finances experienced "windfall" gains from the declining dollar. Now the converse is true. With the Canadian dollar at record highs, the cost of membership is going down. However, the "windfall" gains are gone. For every 1 cent increase in the Canadian dollar, IEEE finances are affected by approximately $3,000.

These are not problems; rather they are opportunities for us to enhance the stature of IEEE and IEEE Canada.

Finally, I want to thank all those IEEE members who made my visits to their Sections more memorable, and also to the student members who made the local arrangements for the Power System Seminar.

Rapport du Président

Lorsque les membres de la Région 7 m'ont élu président de l'IEEE Canada, j'ai dressé un agenda des réalisations que j'espérais accomplir durant les deux ans de ce mandat. Deux ans plus tard, dans ce dernier article, je veux passer en revue ce qui a été accompli. Également, je veux mentionner certain des nouveaux défis auquel fait face l'IEEE.

La principale réalisation a été la mise en place de la nouvelle structure de gouvernance. Le manuel d'opération de la Région 7 a été approuvé cet automne. La révision des Règlements de l'IEEE Canada a été approuvée en juin. La nouvelle structure de gouvernance permet au Comité Exécutif de superviser toutes les activités de la Région 7. Ceci ouvre de nouvelles possibilités dont nous parlerons plus loin.

Coté finances nous avons créé deux comités importants: Vérification et Investissement. Le premier s'est réuni au printemps et a présenté son rapport au comité de direction. Ses recommandations ont été approuvées et font désormais partie de notre manuel d'opération. Le Comité d'Investissement qui a présenté son rapport à Tampa examine comment protéger nos actifs et, encore plus important, comment utiliser nos surplus pour le plus grand bénéfice de l'IEEE Canada.

Un séminaire sur les Systèmes électriques a été créé et présenté à six Section au Canada, à l'Association Professionnelle des Ingénieurs, Géologues et Géophysiciens de l'Alberta, et à la Région 5. J'ai visité douze Sections et célébré avec certaines d'entre elles des anniversaires importants. D'ici la fin de l'année, je vais avoir participé à l'inauguration de deux réalisations d'envergures pour l'IEEE : le HVCC de la rivière Nelson à Winnipeg et la ligne de transmission de 735Kv au Québec.

L'addition d'une troisième réunion concurrente à celle des étudiants a permis au Comité Exécutif d'interagir avec eux. Lors de mes visites de Sections, j'ai tâché de trouver du temps pour rencontrer les membres étudiants. Deux des séminaires sur les Systèmes électriques ont été présentés à la demande de branches étudiantes.

Telus a généreusement établi un prix pour une compétition étudiante. Le premier concours a eu lieu cette année, avec les finales à Vancouver avant les réunions des étudiants et du Comité Exécutif. L'équipe de l'U.Lakehead a remporté le premier prix et présenté son projet lors du souper conjoint Etudiants - Comité Exécutif. L'entente entre Telus et IEEE Canada s'étend sur cinq ans; nous pouvons nous attendre à de nouvelles compétitions au cours des quatre prochaines années.

Grâce au travail acharné de la Section de Québec, le congrès des Sections s'y tiendra en 2008. En août, avec des employés de Piscataway, nous avons visité les installations. Le président de la Section, Paul Fortier, recrute son équipe et je suis sûr qu'avec eux l'IEEE Canada montrera à la communauté de l'IEEE comment elle sait recevoir.

Avant de terminer, je dois attirer votre attention sur deux sujets d'importance pour les membres de l'IEEE Canada:

L'implication des Sections: Le Comité de direction de IEEE Canada et son Comité Exécutif sont là pour aider les Sections à introduire l'IEEE à une nouvelle audience. Une des missions de l'IEEE est d'aider les membres dans leurs carrières. Le Comité Exécutif dépend des Sections pour la dissémination des produits et services de l'IEEE, spécialement l'information technique. Le Comité Exécutif et le Comité de direction peuvent faciliter la livraison de ces programmes, mais il revient aux Sections de les présenter aux membres. Dans ce monde en changement, nous devons remplir notre mission.

Nos finances: Les Trésoriers précédents ont prévenu un impact trop important du déclin du dollar canadien par l'utilisation d'instruments financiers. Ceci a eu un bon et un mauvais coté: il en a coûté plus à nos membres chaque année lors du déclin de la devise canadienne vis-à-vis de la devise américaine; par contre l'IEEE Canada a accumulé de petits gains de taux de changes. Maintenant la situation est inversée. Avec un dollar canadien élevé, le coût pour les membres diminue, mais les gains accumulés ont disparu. Pour chaque augmentation de 1 cent du dollar canadien, les finances de l'IEEE Canada sont affectées par environ $3,000.

Ces sujets ne sont pas que des problèmes: ce sont des occasions d'améliorer la stature de l'IEEE et de IEEE Canada.

J'aimerai, en terminant, remercier tous les membres de IEEE qui ont rendu mémorables mes visites des différentes sections, et les membres étudiants qui se sont occupés des arrangement locaux lors des présentations du séminaire sur les Systèmes électriques.

W.O. (Bill) Kennedy, P.Eng., FEIC, SMIEEE • 2004 - 2005 IEEE Canada President

IEEE Honours Historical Achievement in Electrical Engineering

by Lindsay Ingram, LSIEEE and Public Affairs Manitoba Hydro

Following on the three previous Canadian dedications at DeCew Falls in Ontario (2004) and Signal Hill and Heart's Content in Newfoundland (both in 1985), The Institute of Electrical and Electronics Engineers (IEEE) History Center recently recognized **The Nelson River High Voltage Direct Current (HVDC) Transmission System** as a pioneering engineering project in the long distance transmission of electrical power and energy. The Manitoba Electrical Museum, located in Winnipeg, Manitoba, was the site of the Milestone Dedication Ceremony on June 3rd 2005. Members of the IEEE Winnipeg Section together with Manitoba Hydro staff and retirees as well as other organizations that played a part in the project were in attendance. Mr. Bill Kennedy, President of IEEE Canada, unveiled a commemorative plaque that reads:

IEEE MILESTONE IN ELECTRICAL ENGINEERING AND COMPUTING

HIGH VOLTAGE DIRECT CURRENT, 1972

On 17 June 1972, the Nelson River High Voltage Direct Current (HVDC) transmission system began delivery of electric power. It used the highest operating voltage to deliver the largest amount of power from a remote site to a city. The bipolar scheme gave superior line reliability and the innovative use of the controls added significantly to the overall system capabilities. Finally, the scheme used the largest mercury arc valves ever developed for such an application.

JUNE 2005

INSTITUTE OF ELECTRICAL & ELECTRONICS ENGINEERS

In the 1960s, the key to developing Northern Manitoba's rich hydroelectric resources was finally discovered in the form of long distance high voltage direct current (HVDC) technology. Lower line losses than conventional AC transmission gave HVDC the edge and the system has gone on to prove itself a highly reliable system that is now the backbone of the supply of power and energy, delivering over 75% of the province's electricity output to Manitobans and export customers. Manitoba Hydro has gone on to become world renowned for its expertise and research and development in this field.

Manitoba Hydro's HVDC system consists of two transmission lines carried by two rows of identical steel towers running 895 kilometers from Gillam in northern Manitoba south to the Dorsey converter station close to Winnipeg. One line has its northern terminus at the Radisson converter station close to Gillam and the other extends another 42 kilometers to the Henday converter station. Manitoba Hydro's three largest hydroelectric generating stations are located on the Nelson River at Kettle, Long Spruce, and Limestone, representing a total capacity of 3570 Mw for transmission.

The Government of Canada assisted with a financing agreement to make the project possible. Atomic Energy Canada Ltd. on behalf of the government was responsible for the construction of the project and the primary consultant was Teshmont Consultants LP.

For Manitoba Hydro: Len Bateman, Bob Brennan
For IEEE: Bill Kennedy, Lindsay Ingram, Dr. Ani Gole

Nelson River HVDC Mercury Arc Valves

Construction of the transmission lines began in January 1968 and the first transmission of power took place in June 1972. The two transmission lines, known as Bipole 1 and Bipole 2, consisting of some 4000 guyed steel towers, took about three years to build. Having to traverse large tracts of muskeg country meant that much of the work had to be done during the winter when the ground was frozen.

The three converter stations, comprised of switchyards and converter buildings containing the valves, are extremely large facilities and are the heart of the conversion process. The original Bipole 1 mercury arc valves have now been replaced with solid state thyristor valves.

HVDC transmission of electricity, particularly over such a long distance was relatively new in the late 1960s and '70s. Manitoba Hydro and local engineering consultants specializing in the new technology gained an international reputation for expertise in this technology and visitors from around the world have come to Manitoba to witness the Nelson River system in action. Manitoba consultants and manufacturers have worked on HVDC systems in many parts of the world.

With its high reliability, flexibility of operation, and inherent stability, the Nelson River HVDC Transmission System has proven its worth.

The IEEE Winnipeg Life Members Chapter submitted this Milestone proposal and nomination with the support of Manitoba Hydro staff and retired personnel.

About the Author

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Technological Advances in DSL

1.0 Introduction

The deregulation of the telecommunication in the 90s brought about a competitive environment for broadband technology. Although DSL, *Digital Subscriber Line*, has been late to enter the market compared to cable networks, it has made progress in capturing market share - capitalizing on cost as well as bundling with other services. Figure 1 represents the Top 20 countries in terms of DSL users.

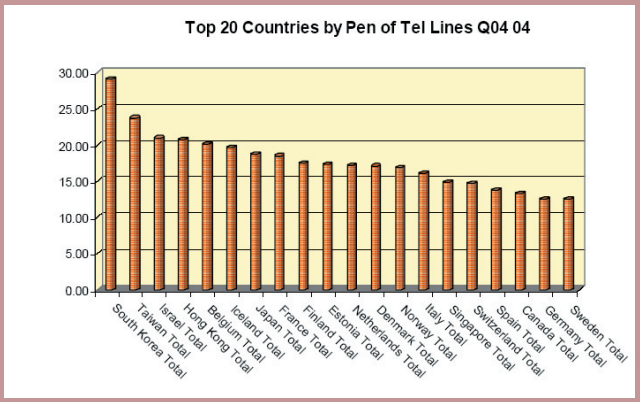

Figure 1 [1]

DSL access technology providers believe that it is the bundling of services such as IP Video over DSL and Voice over IP over DSL to become a Full-Service Network which will give it a competitive edge. These services demand higher bandwidths than those present today. As a result DSL access technology is evolving rapidly, as well as its implementation.

2.0 DSL basics

The premises of DSL technology are:

i. Copper wire can carry a wide range of frequencies well into the MHz range, with limitations only due to the physical characteristics of the wire (IEEE specs rely on testing a UTP category 5 cable to withstand 100MHz)

ii. The maximum information in bits/sec is described by Shannon theorem. This ideally implies that a UTP category 5 cables can carry 100 Mbps.

Although a few MHz of frequencies can be transmitted, only frequencies in the range of (0~4000) Hz are used by telephone lines for voice communications; the rest of the frequencies are not used. It is these unused frequencies that DSL exploits for Broadband Technology. A typical DSL access technology deploys either FDM (*Frequency Division Multiplexing*) or *Echo-Canceling* techniques to transmit and to receive data on a pair of copper wires. The Echo Cancelling technique not only requires sensitivity of Transmitter and Receiver to signals deemed useful but also requires advanced DSP circuitry to achieve good results and is therefore not popular. It is most often superseeded by FDM wherein the entire available frequency bandwidth is divided into 3 or more bandwidths. The 3 basic bandwidths are the following:

1. (0~4) KHz for voice
2. (20~138) KHz Upstream
3. (140 -1100) KHz Downstream.

Based on the upstream and downstream speeds, bit-rate, symmetry factor and number of copper pairs used, DSL is classified as in Table 1. The transmission rates are a function of the thickness and distance of the copper wire being used [9].

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Abstract

The deregulation of Telecommunication in the 1990s has unleashed the Broadband Access technology epitomized by the service provided through the cable networks as well as that provided by DSL through POTS. Furthermore, the rising demand by Internet users for feature rich high bandwidth applications has fuelled the adoption of those technologies – not only by households but also by Small and Medium Enterprises as an economical alternative to expensive leased lines. These obvious business drivers have led broadband access providers to turn copper into gold. The purpose of this paper is to try and put into perspective the DSL technology and its future.

Sommaire

La dérèglementation des télécommunications dans les années '90 a permis la diffusion de technologies d'accès à large bande telles celles fournies par les réseaux câblés et par les réseaux DSL via service téléphonique ordinaire. De plus, la demande croissante provenant des usagers de l'internet pour des applications riches et à large bande a stimulé l'adoption de ces technologies – non seulement par les ménages mais aussi les petites et moyennes entreprises comme alternative économique aux coûteuses lignes dédiées. Ces facteurs commerciaux déterminants ont mené les fournisseurs d'accès à large bande à transmuter le cuivre en or. Le but de cet article et de mettre en perspective la technologie DSL et son avenir.

ATU C/R are the *ADSL Transmission Units* at the *Central* office and *Receiver* ends (also known as the DSL Modem or CSU/DSU), see Figure 2. The splitter is basically a filter used to separate out frequencies in the range of (0-4) KHz, which are used by the telephone lines. The ATU C/R also consists of transmitter and receiver filters. Depending on the type of DSL the transmitter and receiver filter out frequencies consistent with the DSL upstream and downstream bandwidths. Further, the DSL CSU/DSU also performs framing and line coding functions. This system reference model offers the features of interoperability as well as those of scalability for providing Voice-over-IP telephone services.

XDSL	Upstream	Downstream	Bit-Rate	Symmetry	Copper pairs
ADSL	~2Mbps	~640Kbps	N/A	Asymm.	1
HDSL	~1.544 Mbps	~1.544 Mbps	High	Symm.	2
HDSL2	~1.544 Mbps	~1.544 Mbps	High	Symm.	1
RDSL	N/A	N/A	Adaptive	Asymm.	1
SDSL	~1.544 Mbps	~1.544 Mbps	N/A	Symm.	1
VDSL	~2.3 Mbps	~52 Mbps	Variable	Asymm.	1

Table 1: DSL Classification [9]

3.0 DSL and the OSI reference Model

Digital subscriber line is a physical layer technology. However, as with any access technology - The DSL CSU/DSUs i.e. ATU-R and ATU-R performs

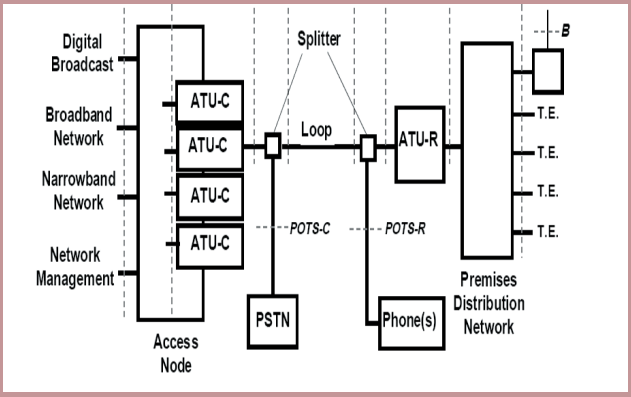

Figure 2: DSL System Reference Model [2]

framing and signaling functions. The framing functions are usually referenced to the Data Link Layer (Layer 2) of the OSI reference model and the DSL line itself is referenced to the physical layer of the OSI reference model. The Layer 2 function of the ATU-R and ATU-C differ in nature since the DSLAM (*DSL Access Multiplexor*) /ATU-C is connected to the Broadband Service provider through an ATM (*Asynchronous Transfer Mode*) network. However the ATU-R and ATU-C communicate in accordance to the implementation of the PPPoE (*Point to Point Protocol over Ethernet*). Being a physical layer technology the ATU C/R provide service to the Data link layer i.e. PPPoE.

Figure 3 illustrates a typical DSL network. The DSLAM/ATU-C is connected to the Broadband Services through the ATM network. The ATU-R relies heavily on the Internet Engineering Task Force Request for Comments (IETF RFC) document RFC 1662 "PPP in HDLC-like Framing" [3].

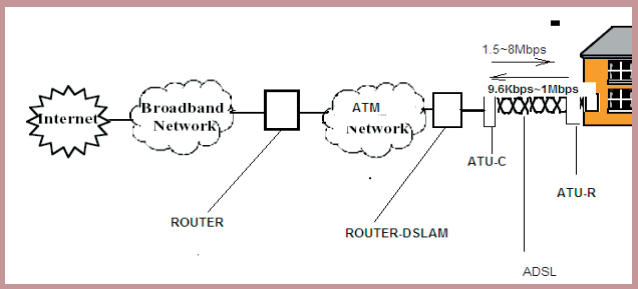

Figure 3: Typical DSL Network [11]

However, depending on the requirements of interfacing a variation to this RFC is often used in accordance to RFC 2516 PPPoE [4]. This is essentially because the user in most cases connects to the ATU-R through the Ethernet. Once these PPPoE frames reach the ATU-C and the DSLAM, the overlay network model as described in RFC 1483 is implemented [3]. The data undergoes the SAR (*Segmentation And Re-assembly*) functions of the ATM following the ATM Frame UNI Format (FUNI) [3]. The ATM FUNI frame format is as illustrated in Figure 4 [3].

This framing conforms to multiplexing techniques defined in RFC 1483 "Multi-Protocol Encapsulation Over ATM AAL5"[3][5]. It is important to note that the PPP connection must be made to Broadband network (server) and not to the DSLAMs. In this way there will be a mechanism to obtain user information for Operation, Administration and Maintenance (OAM). The Network Topology shown in figure 3 widely addresses the current needs of a Home user. However, to address the needs of business users such as those requiring a Branch network, provisions for establishing a VPN (*Virtual Private Network*) tunnel must be made accordingly.

Line Coding

Once the data is framed in the Data Link layer it has to coded into digital signals as well as modulated. A variety of coding and modulation techniques can be deployed. The most popular ones as described by the DSL Forum are the *Discrete Multi Tone* (DMT) and CAP (*Carrierless Amplitude and*

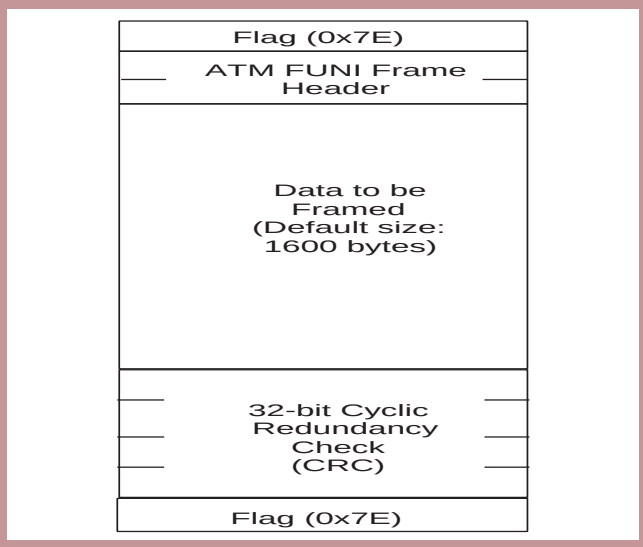

Figure 4: ATM Frame UNI Format [3]

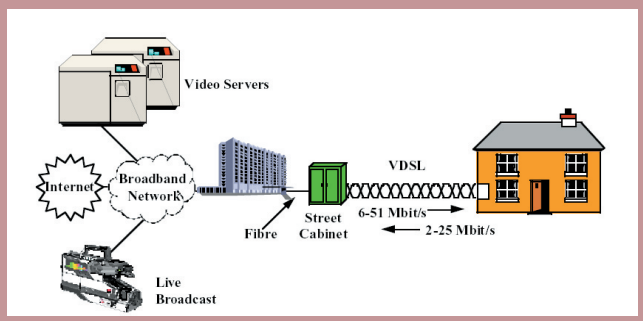

Figure 5: Full-Serviced Network [11]

Phase). DMT is a multi carrier technique. The DMT/ ANSI Standard T1.413standard calls for 256 sub bands of 4 KHz each, wherein the data link frame is encoded using a coding technique such as Reed-Solomon, QAM (*Quadrature Amplitude Modulation*) etc. which results in symbols. These symbols are transmitted on multiple carrier frequencies [6]. Unlike DMT, CAP line-coding uses a single pass band. The Data Link frames are encoded using trellis coding [7][8]. DSL signaling conforms to ITU G.992.1, G.992.2, and ANSI T1.413-Issue 2.The DSL frame in the time domain is recognized by the respective line coding at the beginning and end of the data identifier.

4.0 Future of DSL and the evolution of VDSL

Figure 5 is a typical Full Serviced Network encompassing the goals of Triple Play (convergence, of voice, data and video). The DSL access technology that can cater to these bundling of services is VDSL (*Very high bit rate DSL*). VDSL has been viewed as providing the "last mile" access to the home. A logical approach for VDSL is that the access multiplexer (DSLAM) will now reside at a flexibility point in the network, such as at a FDI/SAC, or in the basement of a multiple-dwelling unit. Therefore, in this instance, it is not possible to migrate CO-based ADSL to VDSL [11].

Further, for the support for QoS (*Quality of Service*) Enabled IP Services for evolving DSL deployment and interconnection, BRAS (*Broadband Remote Access Server*) outlines a common methodology for delivering QoS-enabled applications to DSL subscribers from one or more Service Providers [12]

Figure 6 illustrates the access network incorporating BRAS. The BRAS provides for the aggregation of various services such as ATM, IP, L2TP, and Ethernet etc. Thus, it acts to streamline as well as to provide a common architecture for the access network. BRAS will provide a congestion management function that will allow the synthesis of IP QoS through downstream elements that are not QoS aware, which enables DSL providers to support enhanced IP applications [12].

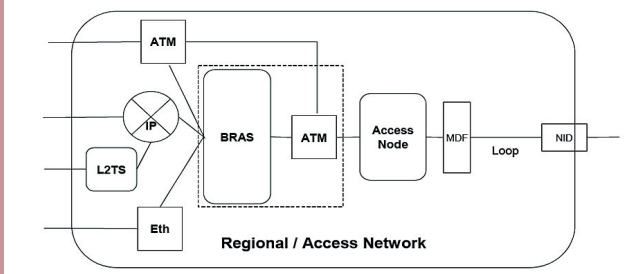

Figure 6: Access network incorporating BRAS [12]

DSL Bonding

DSL Bonding allows two or more DSL lines to be aggregated and provide a single interface whose bandwidth can be appropriately scaled to serve present and future needs, while still leveraging the simplicity and low cost of DSL installation [13].

The major driver for DSL Bonding is to the flexibility of providing a bandwidth that is actually required by the users (a range of bandwidths between those of T1 and T3) and not limited by the standardized bandwidths provided by ADSL or VDSL. This is comparable to the *Inverse Multiplexing over ATM* technique. Suitable DSL technologies for bonding in the residential and video applications include both ADSL and VDSL. This huge bandwidth finds applications in situations where service providers intend to broadcast TV over the Internet, thereby enablingthem to compete with cable TV operators. Figure 7 illustrates the concept of bonding.

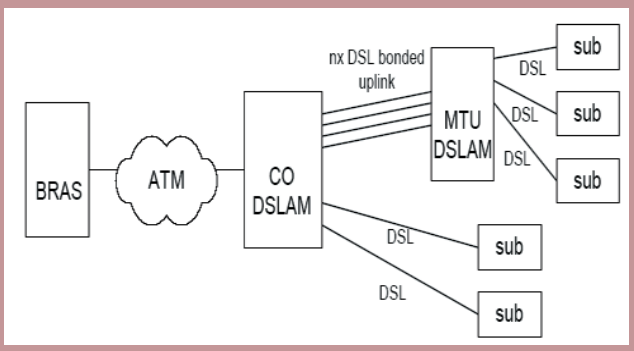

Figure 7: Bonding Concept [13]

DSL Bonding Techniques [13]

i. *Physical Layer Bonding*: The data rates of a number of DSL links are grouped to provide a single link of higher bandwidth. Although this type of bonding has the advantage of protocol transparency, it is limited only to SHDSL as well as the number of lines that can be grouped. SHDSL currently limits bonding to a maximum of 2-pairs.

ii. *ATM Layer Bonding* (IMA): Inverse Multiplexing for ATM (IMA) is fully specified in the ATM Forum standard AFPHY-0086.001 and is applicable to any ATM UNI/NNI including the DSL loop in cases where ATM framing is used over DSL. IMA introduces a common multiplexing sublayer between the ATM layer and the individual ATM. Transmission convergence sublayers of physical links being grouped. An IMA sublayer implementation typically consists of grouping [1,32] SHDSL transceivers.

iii. *Multilink PPP* (ML-PPP): as defined in RFC 1990, it can be used to group multiple PPP links into a single virtual bundle. In the transmit direction, ML-PPP takes a PPP packet, optionally fragments it and forming a new ML-PPP header. Each resulting fragment (or whole packet) is transmitted across a separate physical link. At the receiver, the per-fragment headers are used to reconstruct the complete packets.

Further, ITU / ATIS (T1E1) ratified the G.BOND G.998 standard to allow all DSL technologies to multiplex various data streams. The G.998.1 describes a method for bonding of multiple digital subscriber lines (DSL) to transport ATM streams. G.998.1 describes a method for bonding of multiple digital subscriber lines (DSL) for Ethernet transport. G.998.3 describes a method for bonding of multiple digital subscriber lines (DSL) using *Time-Division Inverse Multiplexing* (TDIM)[15].

5.0 Conclusions

Recent surveys suggest that DSL (Digital Subscriber Line) and IP (Internet Protocol) will be the preferred transport technologies for video in tomorrow's networks. We should see a converged IP-based networks for voice, video and data appear within three years [14]. However, the single biggest hurdle in this direction is government regulation - and not the technology. The number of DSL subscribers has crossed the 100 million mark in 2004. With the bundling of services such as broadcast television, VoIP over DSL, as well as the techniques that have been discussed here, DSL will be viewed as serious competition to the Cable Modem network.

6.0 Acknowledgment

I would like to thank Mr. Frank Chan of Bell Canada for providing valuable insight into the DSL technology.

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About the author

Naresh Kurada obtained his B.Eng. in Instrumentation Engineering from Bangalore University, India in 1996 and started working as an Instrument Engineer in Kuwait. He left for Canada in 1998 and expanded his career into Data Communications. In 2004 he obtained his MSEE with an emphasis in Telecommunications from the University of Texas at Arlington and is currently pursuing his MBA at the Schulich School of Business - York University while working in Data Communications for the Bank of Montreal. Naresh serves in the IEEE Toronto Section as Vice Chair of the PCS Chapter and Newsletter Editor.

Passivity as a Framework for Design and Analysis of Networked Systems: From Power Systems to Formation Flight

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Abstract

Large interconnected dynamical systems characterize many engineering, biological, and societal systems and are expected to be omnipresent in future technologies. Distributed control of electrical power systems, human neural networks, and emerging collective behaviors are example of complex systems whose understanding, although intricate, is fundamental to prediction and control purposes. Analyzing condition of stability of equilibrium for a given system is often a prerequisite in the derivation of mechanisms that allow achieving a desired behavior. The passivity approach, which is reminiscent of circuit theory, is reviewed as a mean to analyze stability of interconnected systems and to design distributed controllers that use local information. It is shown, by means of examples of a power system and a formation of autonomous vehicles, how stability can be warranted from an energy-balance consideration known as passivity.

Sommaire

De nombreux phénomènes, qu'ils soient d'ordre sociétal, biologique ou technologique, résultent de la mise en réseau de systèmes dynamiques. Les réseaux électriques, les réseaux de neurones humains ou l'émergence de comportements collectifs appartiennent à une classe de systèmes que l'on peut qualifier de complexe. Bien que difficile, leur compréhension est néanmoins requise si l'on souhaite prédire et maîtriser leur comportement. Ce faisant, la stabilité du ou des points d'équilibres de tels systèmes est une des notions importantes à considérer. Cet article se propose de revoir le potentiel que présente l'approche de passivité dans l'analyse de la stabilité et la synthèse de commande décentralisée de certains réseaux. Provenant initialement de la théorie des circuits électriques, le formalisme énergétique propre à la passivité permet d'appréhender avec succès l'analyse de certains réseaux tels que les réseaux électriques et le groupement de véhicules autonomes.

1.0 Introduction

Interconnected power systems, control of autonomous vehicles for defence applications [1], and control of communication networks [2] are among complex adaptive networked systems [3] that are either in use today or are emerging and expected to be pervasive technologies in a not so distant future. Such systems are characterized by multiple, possibly simple, and adaptive agents, which are distributedly controlled by feedback of local information. Components of these networked systems may be geographically dispersed and evolving in a competing or cooperating environment. In an environment prompt to rapid changes, distributed control offers the advantages of complying with limited data-rate communication and bounded computation capabilities, and of being more reliable to component failure than centralized control and decision making processes.

However, obtaining a clear understanding of the behavior of networked systems often remains a difficult task. In particular, achieving performance requirements must be accompanied with a guarantee of stability around a desired behavior. Among techniques that allow dynamical system analysis, passivity is an interesting approach to stability analysis of multi-agent dynamical systems for its invariance property through the feedback interconnection of any number of systems. Passivity provides the engineer with a powerful tool for nonlinear systems stability analysis and control synthesis. Passivity-based stabilization of dynamical systems has been investigated quite extensively over the last thirty years [4]-[6]. Induction motors [7], robots [8], smart actuators [9], and haptic environments [10] are among the applications that have benefited from passivity.

We present passivity as a framework for the design and the analysis of networked systems, giving application examples of power systems and formation flight controllers. The basics of passivity are explained, then a general framework for analyzing interconnected systems is described.

2.0 Limitation factors

One of the first results on passivity dates back to the 1950s, where the connection between passivity and stability of linear networks was established by the work of Youla *et al.*, [11], in the context of circuit theory. Passivity can be introduced by considering the RLC circuit of Figure 1.

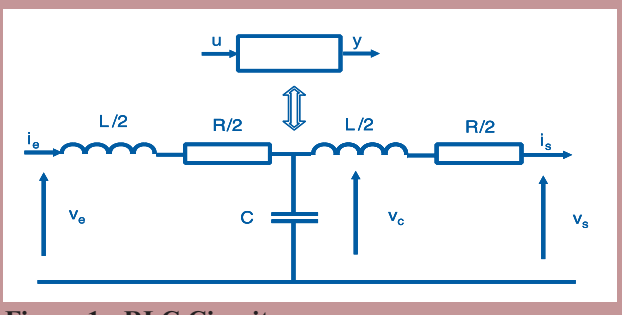

Figure 1: RLC Circuit

Kirchhoff's laws and simple algebraic manipulations lead to the following energy-balance equation:

$$(1)\quad \underbrace{\int_{t_0}^{t} (v_e(\tau)i_e(\tau) - v_s(\tau)i_s(\tau))\,d\tau}_{\text{Supplied and delivered energy}}$$

$$= \underbrace{S(t) - S(t_0)}_{\text{Stored energy}} + \underbrace{\frac{R}{2}\int_{t_0}^{t} (i_e^2(\tau) + i_s^2(\tau))\,d\tau}_{\text{Dissipated energy}}$$

The input-output pair $(u,y) = ((v_e, -i_s),(i_e,v_s))$ is said to be passive with storage function $S(t) = \frac{L}{4}\left(i_e^2 + i_s^2\right) + \frac{C}{2}v_c^2$ and with dissipation in current. More generally, for lumped multi-input multi-output nonlinear systems Σ, passivity expresses an energy-like balance for input-output pair (u,y) characterized by:

$$(2)\quad \underbrace{\int_{t_0}^{t} u^T(\tau)\,y(\tau)\,d\tau}_{\text{Supplied energy}} = \underbrace{S(t) - S(t_0)}_{\text{Stored energy}} + \underbrace{\delta\int_{t_0}^{t} \|y(\tau)\|^2\,d\tau + \varepsilon\int_{t_0}^{t} \|u(\tau)\|^2\,d\tau}_{\text{Dissipated energy}}$$

If δ and ε are zero, the system is lossless. If $\delta>0$ (respectively, $\varepsilon>0$), the system is strictly output passive (respectively, strictly input passive); that is, dissipation occurs at the output or the input, or both. In other words, a passive system is a system that cannot store more energy than supplied.

A memoryless nonlinearity restricted to the first and third quadrants, as illustrated in Figure 2(a), is passive if the *u*-axis is included in the function definition space and strictly passive otherwise. This can be shown

by using (2), given that the product of u and y is always positive and that by definition the stored energy for this element is zero, so that energy is dissipated at all time, unless u or y equals zero. Henceforth, V-I characteristic of a diode and saturation characteristic of a magnetic circuit (without hysteresis) are examples of memoryless passive component models.

For a dynamic model, the phase angle of passive (respectively strictly passive) linear systems is within [$-\pi/2$ rad , $\pi/2$ rad] (respectively, ($-\pi/2$ rad, $\pi/2$ rad)). A complete set of passivity (positive realness) conditions is presented in [12]. Hence, the negative feedback of two strictly passive systems, Σ_1 and Σ_2, has a phase angle less than 180° and is characterized by an infinite gain margin as shown in Fig 2(c).

Relationships between passivity and stability are fundamental results that are well known in the fields of nonlinear systems [4]. Energy-balance inequality (2) with dissipation suggests that one expects stability or at least stabilizability of Σ. From the use of inner product $u^T y$ in (2), passivity is naturally geared to the space (L_2) of finite energy signals. More precisely, from (2) and condition $\delta>0$, it can be shown that strictly output passive systems are bounded-input bounded-output (BIBO) stable in the L_2 space, as illustrated in Figure 2(b). This means that such systems have finite input-output gains. Furthermore, a connection with the internal stability of systems, that is, stability of the states around an equilibrium, can be established provided some form of observability or detectability is met [5].

Circuit theory can be helpful for the understanding of passivity invariance results [13]. For instance, series and parallel connections of passive electrical components, such as resistor, capacitor, and inductor, remain passive. Furthermore, Tellegen's Theorem [13] implies that a network made up of passive N-ports will itself be passive. Equivalent results in mechanics, for instance, can also be found by considering mass, spring, and dashpot. Extension of these facts to nonlinear systems is possible by means of the passivity theorem, which states that the feedback connection of two passive systems is passive [4]-[5]. Several other versions exist that relate strict passivity to input-output stability. Roughly speaking, these theorems result in the invariance of stability or, at least, stabilizability of passive systems that are in a feedback interconnection. This property is particularly well suited to analyze the behavior of networked systems that can be represented as a feedback interconnection of passive or to-be-passivated subsystems [14].

3.0 Passivity and Networked Systems

Networks of dynamical systems are generally represented as sets of ordinary or partial differential equations and a matrix H of operators K_i that models the interconnection structure of the network. K_i is typically used to model the dynamics between two adjacent subsystems that we indistinctively call nodes or agents. For instance, in the context of electrical network, K_i can be a function of impedances between a node i and its adjacent nodes j. The matrix H is often related to the generalized Laplacian of the graph, [15], that characterizes the relationship between neighboring nodes of a network. Adjacency of each node and directedness of edges ($i \rightsquigarrow j$ for directed edge), as illustrated in Figure 3(a), are information embedded in H.

From the structure of Figure 3(b) and applying the passivity theorem, stability of the networked system is obtained if the feedforward-path subsystem is passive and the feedback-path subsystem is strictly passive. Depending on the control system's degrees-of-freedom, forward-path and feedback-path subsystems can be rendered passive, if not already, provided some structural properties of each subsystem is satisfied [5].

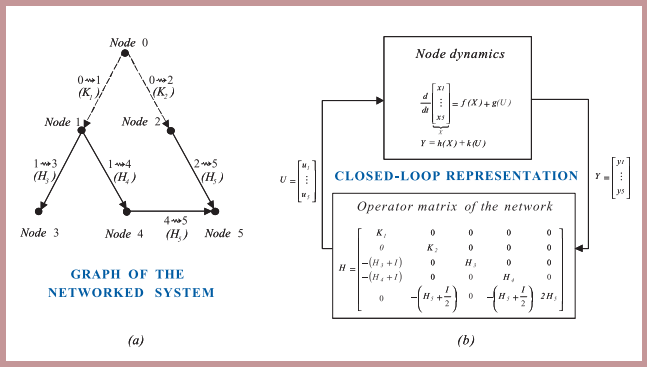

Figure 3: Graph and closed-loop representation of a network system

Passivity techniques have been recently used to solve stabilization problem of multi-agent systems. For instance, the interpretation of an optimization-based network flow control as a closed-loop system and the use of passivity can be used to prove the stability of a class of network flow regulation, which is typical of internet congestion control [16]. This approach has also been used for the decentralized power control of code division multiple access systems. A gradient-based law, which is obtained from a game-theoretical formulation, is shown to converge to a Nash equilibrium by means of passivity argument applied to a closed-loop model that results from the feedback interpretation of an optimization problem [17].

4.0 Passivity for the Stability Analysis of Electrical Power Systems

Passivity can be used to analyze power systems stability when the networked system is faced with: (i) voltage disturbance $\tilde{\mathbf{v}}_o$ located at an observation point or a connection point o to another subnetwork; (ii) disturbance $\tilde{\mathbf{v}}_{cj}^{\delta}$ at a point where the electrical component C_j is connected to the power grid (Figure 4). In order to work within an input-output point of view, the power system is decomposed by using the component-oriented modeling technique [18]. By component is meant an electrical load, a generator or a compensator. Figure 3(b) suggests an obvious closed-loop interpretation for electrical power network, where the power grid is represented by an admittance matrix H. Each component connected to the network is modeled as a voltage or current source in feedback with H as shown in Figure 4. Each component or aggregate of components is supposed to be controllable through channels $\mathbf{u}_{yi}$ and $\mathbf{u}_{ci}$. When no perturbation occurs, the system lies in its equilibrium point ${}^0x$; when perturbations occur, the system is described with error signals $\tilde{x}=x-{}^0x$, where x is any current i and voltage v of the network.

Assume the power grid can be approximated as a linear time-invariant N-port. To ensure strict passivity of the forward-path subsystem of Figure 4, the complex admittance $H(j\omega)$ has to verify the following strict-positive realness constraint $H(s-\varepsilon) + H^*(s-\varepsilon) \geq 0$ for $\mathrm{Re}(s) \geq 0$ and some $\varepsilon > 0$.

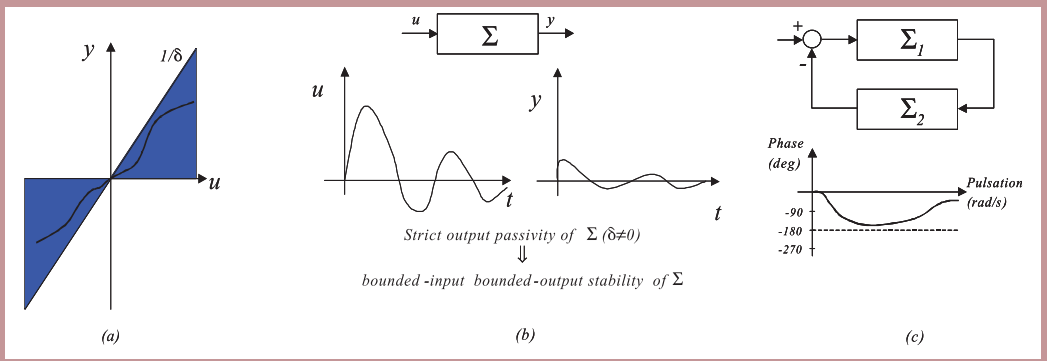

Figure 2: Input-output sector and energy properties

It was proven in [19] that a radial power network whose lines are represented with the T-equivalent model shown for one phase in Figure 1, is strictly input passive with only current source components. A generalization to both types of components in feedback necessitates considering small parasitic shunt resistances in parallel with C_j.

A direct application of passivity theorem indicates that finite-energy stability is obtained if each component or aggregate of components is passive or has

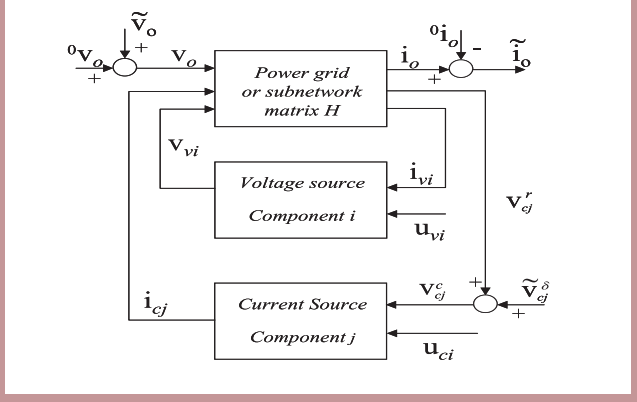

Figure 4: Component-oriented modelling of an electrical power system

been passivated by means of control actions $\mathbf{u}_{vi}$ and $\mathbf{u}_{ci}$. If the disturbance vanishes or the fault is cleared, asymptotic convergence of the network state can also be shown [19]. Article [19] and references therein draw a list of passivated electrical components such as turbo-alternators, induction motors, and a class of FACTS, namely, STATCOM, which could be used to passivate a load aggregate rather than rendering each and every single load passive. Conditions can also be given so that specific classes of aggregate loads, large motor, thermostatic heater, and on-load tap changer are passive or quasipassive where, in the latter case, sector condition related to passivity is lost in a region containing the equilibrium.

Component C_j is not limited to being a single electrical apparatus. Indeed, the network of Figure 4 could be connected at point o to another network by means of admittance matrix H, which would have to satisfy condition (3). Furthermore, if some components or aggregate of components are not, or cannot, be made passive, weaker stability such as BIBO in magnitude ($L\infty$ space) may be obtained provided some form of quasipassivity is observed [19].

There exist classes of mechanical systems, such as robots, that are naturally found passive from force or torque input to speed or angular rate output. Equilibrium is characterized by zero speed, which means that the amount of energy necessary to steer the perturbed system to an equilibrium is finite. It is not necessarily so with electric systems whose equilibrium is not characterized by zero current or zero voltage. Passivity is therefore applied to error dynamics whose equilibrium is $\tilde{x} = 0$. Other approach and passivation schemes, which circumvent the finite dissipation obstacle, are discussed in [20], [21].

5.0 Passivity for Formation Flight Control Design

Designing decentralized controllers for a formation of autonomous vehicles can be tackled by means of passivity arguments. Each vehicle control only feeds back information from its neighbors such as relative distance and speed. Vehicles are considered neighbors to agent i as long as they are located in a region defined by their sensor range limits of i.

There exist several definitions for analyzing the stability of a formation of autonomous vehicles. Mesh stability is defined as the combination of the Lyapunov stability of interconnected systems with the input-output stability of inner subsystems [22]. String stability is the one-dimensional equivalent of mesh stability and is of interest mainly in automated highway systems [23].

In the context of leader-follower maneuvers, it is interesting to analyze the behavior of the formation when the leader tracks a smooth curve and to verify that stability is maintained in case of disturbance applied to the nodes. Achieving stable formation morphing can also be addressed by means of passivity. Simply stated, the concept of formation morphing is defined here as performing set-point regulation of the changing relative distances between neighboring vehicles with a time-invariant graph topology of the formation. Achieving stable morphing can be useful, for instance, in inspection tasks during which the vehicle formation has to expand and to contract its geometry to comply with the geometrical constraints imposed by the environment, such as when transiting from wide open areas to constrained spaces.

As suggested by Figure 5, the formation dynamics can be decomposed into two classes of dynamics: (i) dynamics of nodes L and F_i; (ii) dynamics of controllers that virtually link two neighbors. A physical interpretation of such networked systems is given by the representation of interconnected vehicle dynamics as virtual springs and dampers shown in Figure 5. The spring-damper interpretation of the networked system allows the designer to adopt the closed-loop system viewpoint of Figure 3(b), where the matrix H embeds the interconnection structure, and the virtual mechanical components, which are represented by operators H_1, H_2, K_3, K_4, and K_5. The control law applied to each vehicle is composed of two loops. One loop is dedicated to the passivation of the local node. The other loop feeds back relative distance and speed between neighbors and is represented by one of the aforementioned operators, which are designed to render H strictly passive. These control schemes aim at achieving:

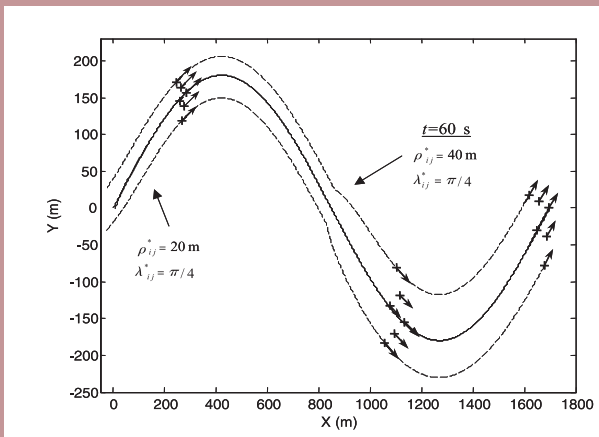

Figure 6: Time evolution of the formation with large relative position commands $\rho^*_{ij}(0) = 20$ m & $\rho^*_{ij}(60) = 40$ m

- stable trajectory tracking with respect to disturbances (leader and followers);
- robustness with respect to parametic uncertainties in the dynamics;
- stable piecewise-constant morphing of the formation.

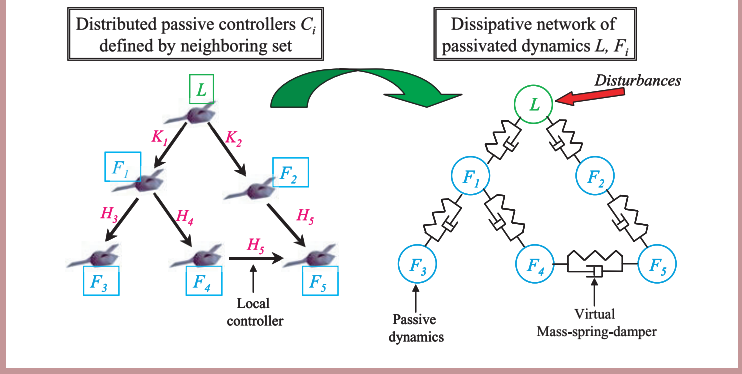

Figure 5: Physical analogy of formation flight control through passivity

As an example, a formation of six vehicles with the interconnection graph of Figure 5 is required to track a sinusoidal trajectory and to stabilize the inner relative positions among the vehicles at the range of 40 m at time t=60 s from an initial relative position of 20 m. For the sake of clarity, only the trajectory of the leader and of nodes 3 and 5 are shown in Figure 6.

The arrow represents the speed vector of each vehicle. It is shown that the decentralized

two-loop passivity-based control law stabilizes the formation. More precisely, stable set-point regulation of inner relative distance and of line-of-sight angle between neighboring vehicles is achieved while the leader is asked to follow a smooth curve.

6.0 Prospective application to automated highway

A particular application on the 1D version of the leader-to-follower stability problem, which can be related to string stability [23], is the automated highway; see for instance the California PATH project in [24]. In some situations, car drivers perform decentralized control of their vehicle based on perception of their neighbor's behavior. A particular topic of interest would consist of analyzing, by means of passivity, the stability of a platoon of cars in response to an abrupt deceleration of the leader. Driver's reaction delay, too small inter-car separation along with high speed are among a set of conditions that are likely to lead to string instability of the platoon with potentially dramatic consequences such as car pile-ups downstream in the string. The use of appropriate slowdown warning systems and conditions to maintain safe relative distances despite abrupt contingencies could be derived by adopting a setting similar to the planar vehicle formation control.

7.0 Acknowledgement

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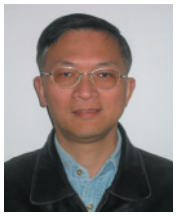

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Ingénierie des exigences - L'outil de support GenSpec

1.0 Introduction

Cet article[1] présente GenSpec, l'outil de support à l'ingénierie des exigences développé à Hydro-Québec: le domaine de l'ingénierie des exigences; les problèmes les plus souvent rencontrés dans ce domaine; une solution à ces problèmes, GenSpec; et ses avantages.

L'article s'adresse à toute personne concernée par la définition des exigences d'un produit ou service. Par produit, on entend tout système ou sous-système tel qu'une installation, un équipement, un appareil, un composant matériel ou un composant logiciel.

2.0 Domaine de l'ingénierie des exigences

2.1 Contexte

L'ingénierie des exigences est une activité du processus de fourniture et d'acquisition. Elle fait le lien entre le client et le fournisseur. Ses intrants sont les besoins ou exigences brutes spécifiés par le client. Ses extrants sont les documents d'exigences: norme, appel d'offres, contrat, devis, cahier des charges, spécification, etc.

2.2 Contenu

L'ingénierie des exigences inclut:

a. la collecte, l'analyse, la filtration, la complémentation, la caractérisation, la structuration, la liaison et la documentation des exigences;
b. la négociation des exigences avec le client et le fournisseur;
c. l'implantation et le suivi de la traçabilité des exigences;
d. la gestion des modifications d'exigences.

2.3 Importance

L'ingénierie des exigences est une activité très importante du processus de fourniture et d'acquisition. À tel point que, si elle est négligée, plusieurs besoins du client ne sont jamais compris par le fournisseur ou ne le sont qu'après ou peu avant la livraison. Il en découle les problèmes majeurs suivants:

a. Augmentation des coûts et délais de réalisation: la compréhension d'un besoin après ou peu avant la livraison implique souvent de recommencer la réalisation, au moins en partie.
b. Diminution de la qualité: l'incompréhension d'un besoin implique que le produit ne répondra pas à ce besoin; et la compréhension d'un besoin après ou peu avant la livraison implique souvent que le produit ne répondra pas à ce besoin ou ne sera que sommairement corrigé pour y répondre le mieux possible.

L'ingénierie des exigences est une activité non seulement importante mais aussi essentielle à la fourniture et à l'acquisition. En effet, les exigences sont la base de l'entente client-fournisseur. De surcroît, elles sont la base de la fourniture et de l'acquisition: base de réalisation; base de validation et d'acceptation par le client; base de documentation.

3.0 Problèmes les plus souvent rencontrés

3.1 Exigences coûteuses

L'ingénierie des exigences est une activité souvent coûteuse, pour les raisons suivantes:

3.1.1 Exigences incluant moyens de réalisation: les exigences ne font pas abstraction des moyens de réalisation. Lorsque survient un changement de ces moyens, l'ingénierie des exigences doit être recommencée. Cela occasionne des coûts supplémentaires importants, en particulier lors d'un changement de technologie.

[1] L'article fait suite à un autre publié à l'automne 2004 dans la Revue canadienne de l'IEEE [1].

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Sommaire

Faisant le lien entre le client et le fournisseur, l'ingénierie des exigences est une activité très importante du processus de fourniture et d'acquisition. Or, elle est souvent négligée, l'accent étant mis sur la réalisation. De ce fait, plusieurs besoins du client ne sont jamais compris par le fournisseur ou ne le sont qu'après ou peu avant la livraison. Il en découle des problèmes majeurs de coûts et de qualité de produit (ou service). Pour résoudre ces problèmes, Hydro-Québec a développé un outil en 2001: GenSpec. Ce dernier permet l'entrée des exigences dans une base de données, quelques vérifications automatiques de ces exigences et la génération de documents d'exigences. Rigoureusement basé sur des normes internationales GenSpec vise à (1) réduire le coût de l'ingénierie des exigences, (2) faciliter la compréhension des exigences et (3) spécifier des exigences correctes, i.e. exactes, complètes, cohérentes et validables. Une version gratuite et complète de l'outil est disponible sur demande.

Abstract

Making the link between the client and the provider, requirements engineering is an important part of the procurement process. However, it is often neglected, the focus being on realization. Hence, many client needs are never understood by the provider, or they are only after or shortly before release. This results in major cost and product (or service) quality problems. To resolve this, Hydro-Québec has developed a tool in 2001: GenSpec. It allows the input of requirements in a database, a few automated verifications of those requirements and the generation of requirements documents. Rigorously based on international standards, GenSpec attempts to (1) reduce the cost of requirements engineering, (2) facilitate the understanding of requirements, and (3) specify requirements that are correct, i.e. accurate, complete, coherent and verifiable. A free version of this tool is available on demand.

Exemple: En 1990, un système est développé et l'ingénierie des exigences ne fait pas abstraction des moyens de réalisation. En 2000, les technologies utilisées sont obsolètes. Pour pallier ce problème, un nouveau système répondant aux mêmes besoins est développé: nouvelles technologies, nouvelle architecture. L'ingénierie des exigences est alors recommencée, une charge de travail de plusieurs personnes-années; pourtant, les besoins n'ont pas changé, sauf exceptions.

Le Tableau 1 relie les problèmes avec la solution GenSpec.

Problème	Solution
3.1.1	5.1f) [5.4b)]
3.1.2	5.1b) ; 5.1d) ; 5.1f) [5.2a)]
3.1.3	5.1a) ; 5.1c)
3.1.4	Solutions aux problèmes 3.2.1 à 3.3.4
3.2.1	5.2a)
3.2.2	5.2b) ; 5.2c) ; 5.2d)
3.2.3	5.2a) ; 5.2b)
3.3.1	5.3a) ; 5.3b) ; 5.3c) ; 5.3d) ; 5.3e) ; 5.3g) ; 5.3h) [5.2b)]
3.3.2	5.3a) ; 5.3b) ; 5.3c) ; 5.3d) ; 5.3e) ; 5.3g) ; 5.3h) [5.4a);5.4d)]
3.3.3	5.3c) ; 5.3f) ; 5.3h) [5.1c)]
3.3.4	5.3e) ; 5.3h) [5.4b)]

Tableau 1: Liens problème-solution

3.1.2 Exigences mal structurées: les exigences ne sont pas bien structurées. Lorsque survient le moment de modifier une exigence, cela a des répercussions sur plusieurs autres exigences non clairement identifiées. Cela exige de revoir l'ensemble des exigences.

3.1.3 Formatage manuel non normalisé: le format de présentation de chacune des exigences n'est pas automatique ou formellement normalisé. Lorsque survient une modification de format d'une exigence, il faut revoir le format des autres, afin d'assurer l'uniformité et ainsi faciliter la lecture.

3.1.4 Exigences difficiles à comprendre ou incorrectes: les exigences sont difficiles à comprendre ou incorrectes du point de vue du client ou du fournisseur. Cela exige de revoir les exigences à plusieurs reprises, constituant en effet une autre raison pour laquelle l'ingénierie des exigences est une activité souvent coûteuse.

3.2 Exigences difficiles à comprendre

Les exigences sont souvent difficiles à comprendre, pour les raisons suivantes:

3.2.1 Exigences mal structurées:

a. Mal regroupées: certaines exigences semblent regroupées de façon arbitraire.

b. Non graduelles: plusieurs exigences ne sont pas présentées de façon graduelle, de la vue d'ensemble à la vue détaillée.

c. Cachées: plusieurs exigences sont « cachées » dans un même paragraphe, parmi d'autres informations complémentaires. En effet, elles ne sont pas clairement identifiées par un code, un numéro ou l'utilisation d'un verbe d'exigence tel « devoir ». Conséquemment, des exigences sont escamotées lors de la réalisation ou de la validation.

3.2.2 Exigences ambiguës: elles ont plusieurs interprétations possibles. Elles peuvent être claires pour le client mais ambiguës pour le fournisseur, ou inversement, le contexte du client étant différent de celui du fournisseur.

Exemple: « Le système doit permettre la télécommande » Pour le client Hydro-Québec, dans le contexte d'un poste électrique, « télécommande » désigne une télécommande d'un appareil du poste effectuée de l'extérieur du poste. Pour le fournisseur, cela peut désigner en plus une télécommande de cet appareil effectuée de l'intérieur du poste.

3.2.3 Exigences difficilement retraçables: il est difficile voire impossible de trouver l'exigence source de laquelle elles découlent, en particulier lorsque cette exigence source est spécifiée dans un autre document.

3.3 Exigences incorrectes

Les exigences sont souvent incorrectes, pour les raisons suivantes:

3.3.1 Exigences inexactes: le produit n'a pas à répondre à ces exigences du point de vue du client ou du fournisseur. Elles proviennent généralement d'une incompréhension du besoin ou d'un problème de gestion des modifications d'exigences.

3.3.2 Exigences incomplètes: elles ne couvrent pas tous les intrants et extrants requis, toutes les fonctions requises ou toutes autres caractéristiques telles les performances requises; ou elles ne sont pas priorisées, ne fournissement pas toutes les informations nécessaires à leur compréhension ou comportent l'expression « à déterminer ».

3.3.3 Exigences incohérentes: elles se contredisent ou utilisent des mots différents pour traiter des mêmes sujets.

3.3.4 Exigences invalidables: il n'existe aucune procédure acceptable permettant de les valider. Ces exigences utilisent souvent des intrants ou extrants internes ou des mots imprécis tels que « habituel », « rapide » ou « convivial ».

EXEMPLE - L'exigence suivante « Le système doit faire la somme des puissances consommées » n'est pas validable si son extrant, cette somme, n'est pas disponible sur une interface externe tel un écran.

4.0 Solution: l'outil GenSpec

4.1 Description générale

Pour résoudre ces problèmes, Hydro-Québec a développé un outil en 2001: GenSpec. Ce dernier permet l'entrée des exigences dans une base de données, quelques vérifications automatiques de ces exigences et la génération de documents d'exigences. La Figure 1 présente son interface personne-machine: à droite apparaît l'arbre d'exigences; à gauche, le formulaire d'entrée de l'exigence sélectionnée.

GenSpec a été développé notamment à partir de normes internationales [2][3][4][5] et de documents de la NASA [6][7] et de la Défense des États-Unis d'Amérique [8]:

a. exigences hiérarchisées,

b. une seule exigence par paragraphe,

c. un numéro de référence unique par exigence,

d. etc.

En particulier, la norme 12207 de ISO/CEI/IEEE [5], un document de très haute qualité, a été utilisée comme « modèle » de document d'exigences.

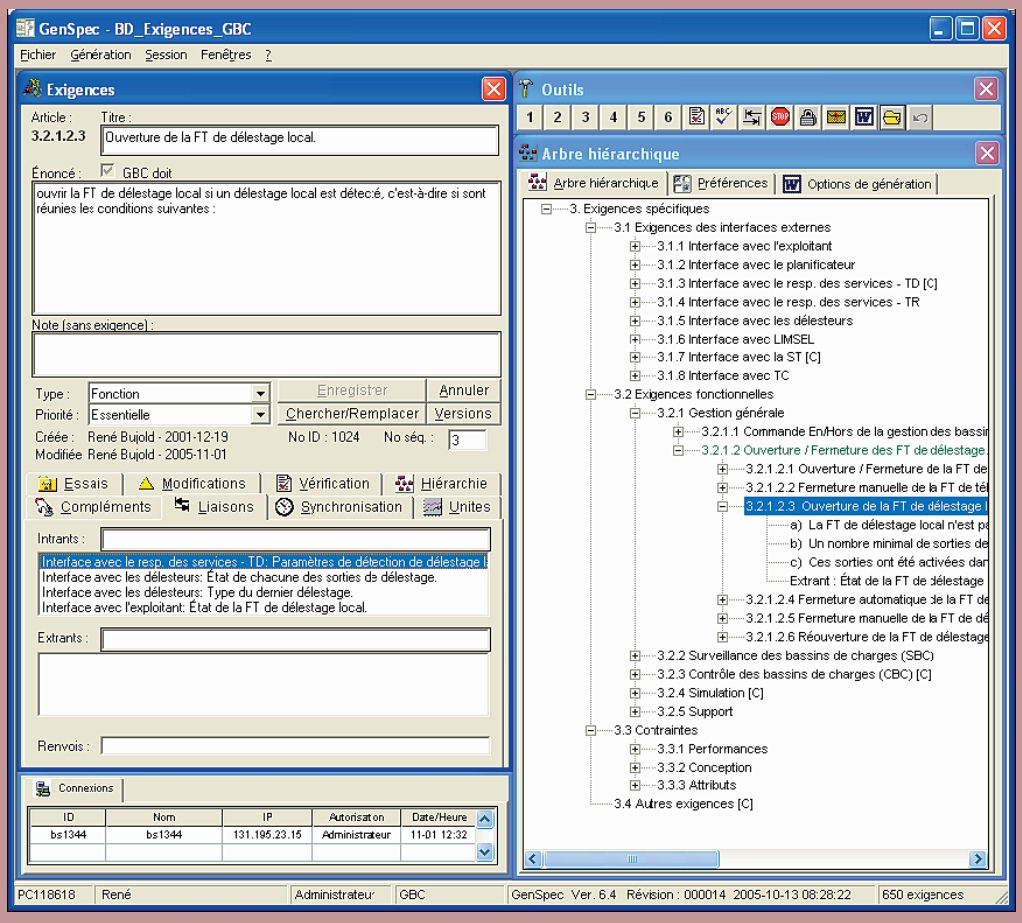

Figure 1: GenSpec

4.2 Fonctions principales

4.2.1 Définition des exigences: cette fonction permet à plusieurs utilisateurs en même temps (multi-utilisateur) d'entrer ou de modifier des exigences; elle supporte notamment les commandes Chercher et Remplacer (voir Figure 2).

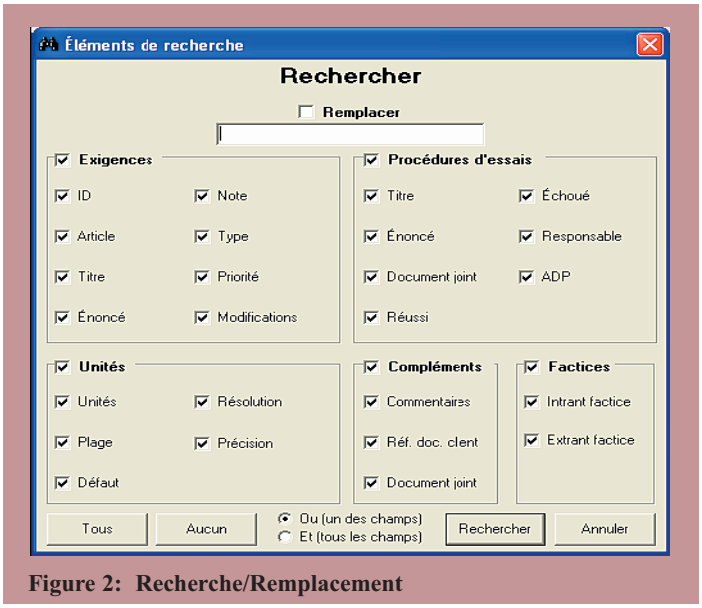

Figure 2: Recherche/Remplacement

De plus, elle permet de générer les documents d'exigences: spécification, arbre d'exigences, etc. (voir Figure 3).

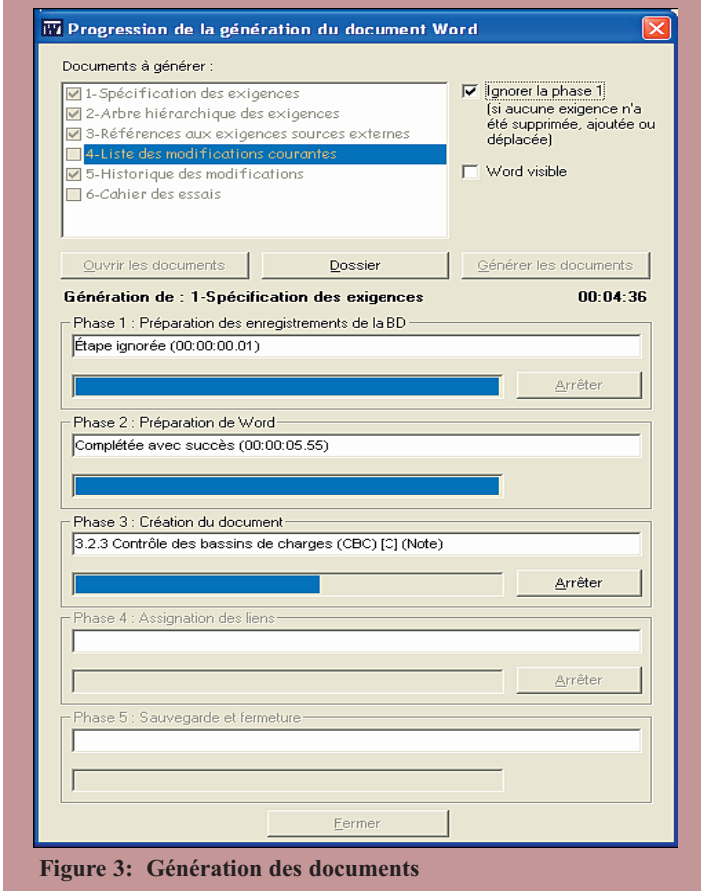

Figure 3: Génération des documents

4.2.2 Caractérisation des exigences: par exigence, cette fonction génère un numéro de référence unique et permet d'entrer l'identification de la source (référence à un paragraphe d'un autre document), la priorité, une note, un commentaire et un fichier joint, tous pouvant être générés dans le document d'exigences. À la demande, les exigences commentées apparaissent en vert dans l'arbre d'exigences.

4.2.3 Structuration et liaison des exigences: cette fonction permet de structurer et de lier les exigences (renvois) par de simples commandes clic et glisse. De plus, elle offre des facilités de navigation telle une commande d'aller-retour rapide entre l'origine et la destination d'un lien. À la demande, les exigences reliées apparaissent en bleu dans l'arbre d'exigences.

4.2.4 Évaluation de conformité aux exigences: par exigence, cette fonction permet d'entrer des procédures d'évaluation de conformité, et le résultat de cette évaluation. De plus, elle permet de générer un rapport d'évaluation contenant les exigences, leurs procédures d'évaluation et les résultats de cette évaluation.

4.3 Fonctions secondaires

4.3.1 Contrôle et analyse des exigences: cette fonction empêche d'introduire des incohérences de hiérarchie ou de liaison d'exigences - règles de hiérarchie et de liaison paramétrables - et, en particulier, de supprimer une exigence à laquelle d'autres renvoient. De plus, elle offre un vérificateur d'exigences (voir Figure 4), y compris un vérificateur d'orthographe et de grammaire. De surcroît, elle permet de générer un tableau Sources Vs Exigences, facilitant la vérification de l'exactitude des exigences. À la demande, les exigences en erreur apparaissent en rouge dans l'arbre d'exigences.

4.3.2 Normalisation des exigences: cette fonction permet de générer automatiquement des textes de début d'exigence selon le type d'exigence - texte et type paramétrables. De plus, elle permet de définir et d'utiliser des variables dans les textes d'exigences.

4.3.3 Configuration des documents d'exigences: cette fonction offre une grande quantité d'options de formatage des documents générés; elle permet notamment d'en exclure des exigences et d'en inclure d'autres avec la mention « Non applicable ».

4.3.4 Gestion de l'historique des exigences: cette fonction permet d'entrer et de visualiser la raison de modification d'une exigence par rapport à la version antérieure, et d'enregistrer une version formelle de l'ensemble des exigences. De plus, elle permet de comparer la version actuelle avec une version antérieure, et de ramener une ou toutes les exigences telles qu'elles étaient à une version antérieure. Enfin, elle permet de générer un tableau Historique des modifications d'exigence. En complément, elle permet d'enregistrer de simples copies de sécurité des exigences.

5.0 Avantages

Cette section présente les avantages de GenSpec par rapport à un logiciel de traitement de texte:

5.1 Réduction des coûts

GenSpec réduit les coûts de l'ingénierie des exigences:

a. Concentre les efforts sur les exigences plutôt que sur le formatage, les documents étant générés automatiquement.
b. Permet de structurer facilement les exigences.
c. Permet de générer automatiquement des textes de début d'exigence, aidant, de surcroît, à la normalisation.
d. Facilite la liaison des exigences.
e. Génère automatiquement le rapport d'évaluation.
f. Facilite la lecture (5.2), réduit la quantité d'erreurs (5.3) et respecte des normes internationales (5.4).

5.2 Facilitation de la lecture

GenSpec facilite la lecture des exigences:

a. Oriente à bien structurer les exigences, un paragraphe par exigence, graduellement, de la vue d'ensemble à la vue détaillée, basé sur une notion d'arbre d'exigences: exigences parents sous lesquelles se retrouvent des exigences enfants, les exigences parents étant la synthèse (vue d'ensemble) de leurs enfants.
b. Permet de lier chacune des exigences aux besoins du client ou exigences sources.
c. Offre une grande quantité d'options de formatage des documents générés.
d. Uniformise les documents d'exigences, parce que générés automatiquement.

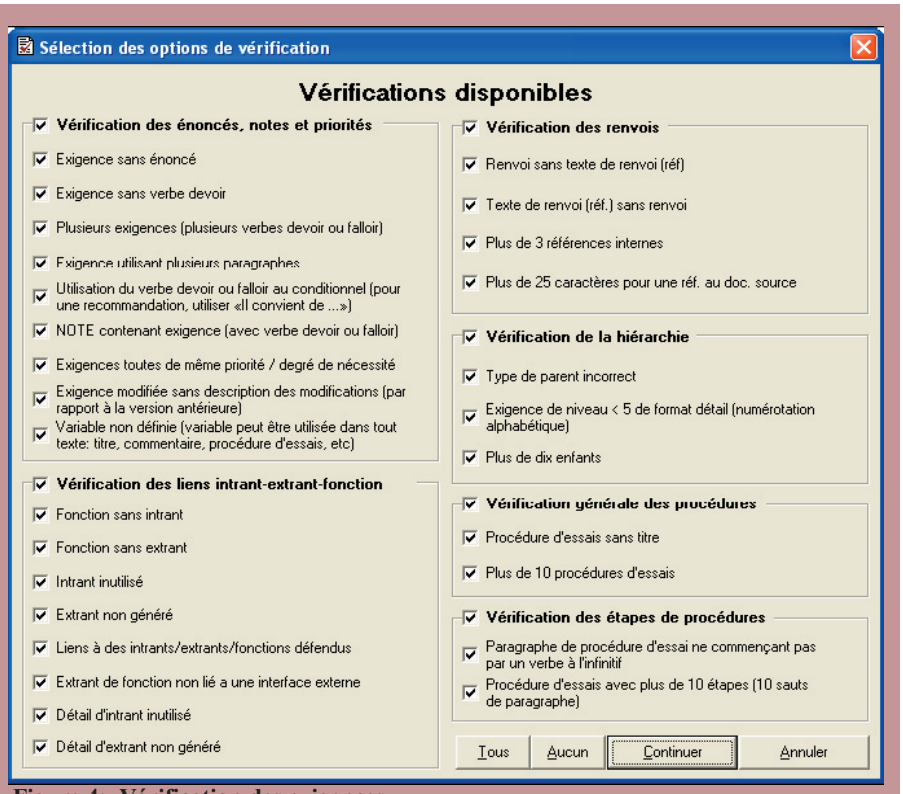

Figure 4: Vérification des exigences

e. Réduit la quantité d'erreurs (5.3) et respecte des normes internationales (5.4).

5.3 Réduction de la quantité d'erreurs

GenSpec réduit la quantité d'erreurs d'exigences:

a. Génère un tableau de vérification: Sources Vs Exigences.
b. Facilite la couverture de l'ensemble des exigences: définition de tous les intrants et extrants sur les interfaces externes et liaison de chacun d'eux aux fonctions, et inversement.
c. Empêche d'introduire des incohérences de hiérarchie ou de liaison d'exigences.
d. Simplifie les corrections et mises à jour des exigences et des procédures d'évaluation, ces procédures étant définies avec les exigences.
e. Offre un vérificateur d'exigences (voir Figure 4).
f. Permet d'utiliser des variables dans les textes d'exigences.
g. Gère un historique des modifications d'exigence.
h. Facilite la lecture (5.2) et respecte des normes internationales (5.4).

5.4 Respect des normes internationales

GenSpec respecte des normes internationales, dont les normes pertinentes de IEEE [2][3] et de ISO/CEI [4]:

a. Fixe un numéro de référence unique par exigence.
b. Oriente à énoncer des exigences validables, faisant abstraction des moyens de réalisation, les intrants et extrants d'exigences ne pouvant être que ceux des interfaces externes.
c. Facilite la modification des exigences, étant bien structurées et les liens entre exigences étant clairement définis: liens parent-enfant, liens intrant-extrant-fonction et autres liens (renvois).
d. Définit la priorité de chacune des exigences.

6.0 Conclusion

Plusieurs problèmes importants sont rencontrés en ingénierie des exigences: près d'une douzaine identifiée à 3.0. Compte tenu de l'importance de cette activité, de ses impacts majeurs sur les coûts et la qualité des produits (ou services), il est hautement souhaitable que ces problèmes soient résolus.

GenSpec apporte une solution, tel que montré par le Tableau 1. Assurément, il impose la rigueur nécessaire à cette ingénierie et augmente la qualité des documents d'exigences.

Pour ces raisons, depuis 2002, il est formellement convenu à la direction Expertise d'Hydro-Québec Équipement d'utiliser cet outil pour l'ingénierie des exigences de tous ses automatismes.

GenSpec est par ailleurs toujours en cours d'évolution. Pour les intéressés, il n'est pas prévu de le commercialiser, même à long terme. Cependant, une version gratuite et complète, mais non supportée, de l'outil est disponible sur demande. À cet égard, plusieurs se sont déjà montrés intéressés : Universités (Paris, Ottawa, etc), Centres de recherche (CNRS, ONERA, etc), Entreprises publiques ou privées (Ministère de la Défense de la République Française, Desjardins, etc) et Associations professionnelles (IEEE Internationale, AFIS, etc).

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8.0 Remerciements

André Lemire, Van Thich Nguyen, Michel Ouellet, Pierre-N. Robillard, Michel Vincelette.

À propos de l'auteur

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René Bujold est ingénieur à la direction Expertise d'Hydro Québec Équipement. Diplômé de l'École de technologie supérieure en 1988, Membre de l'Ordre des ingénieurs du Québec, il a oeuvré dans tous les aspects du développement de système: étude d'avant-projet, ingénierie des exigences, conception matérielle et logicielle, implémentation, vérification et validation, etc. Au cours de ces années, il a développé un intérêt particulier pour l'activité fondamentale et la plus problématique du processus de développement: l'ingénierie des exigences. Il est à l'origine et le responsable du développement de l'outil GenSpec.

Adaptive Routing Algorithms for All-Optical Networks

by *Rolland Mêwanou, Samuel Pierre*
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Abstract

This paper proposes two new heuristic algorithms based on link-state for the dynamic routing problem in optical networks deprived of wavelength converters. In those networks, dynamic routing consists of transmitting data over unique wavelengths along dynamically established paths, while trying to minimize blocking probabilities of call requests. Both new algorithms were implemented and tested within ring topology and achieved satisfactory performance when compared to former algorithms such as FPLC and LLR algorithms.

Sommaire

Cet article propose deux algorithmes heuristiques basés sur le "link-state" pour le problème de routage dynamique dans les réseaux optiques sans convertisseurs de longueurs d'ondes. Dans ces réseaux, le routage dynamique consiste à transmettre des données sur des longueurs d'ondes uniques selon des chemins établis dynamiquement, tout en tentant de minimiser les probabilités de blocage des requêtes d'appel. Ces deux nouveaux algorithmes ont été implantés et testés sur une topologie en anneau et ont atteint une performance satisfaisante comparés aux algorithmes précédents tels que FPLC et LLR.

Index

Link-state routing, optical routing, routing and wavelength assignment (RWA), wavelength division multiplexing (WDM).

1.0 Introduction

In the last decades, many applications have been limited by the bandwidth allowed by carrier networks. Nowadays, optical networks based on *wavelength division multiplexing* (WDM) technology offer high-speed rate of data transfer combined with high reliability of the transmission channels. They convey data on light wavelengths through optical fibers. Physically, two requests cannot be transmitted simultaneously on the same wavelength, so it is mandatory to find the best way to allocate network resources in order to support heavy traffic. Since optical routers have high switching frequencies and no waiting queues for data transmitted, it is critical to find routing path for each request sent to these networks. In all-optical networks, each routing path is called *lightpath* and used a unique wavelength during its lifetime. This constraint is the *wavelength continuity constraint* (WCC).

Optical routing algorithms that predetermine a unique path for any connection requested between two nodes, are called *static,* whereas those that respond to each request by taking into account the links' state before choosing a path among a set of candidate paths are known as *dynamic*. In dynamic routing problem, for a set of requests between source-destination pairs (s-d) coming dynamically to the nodes, we have to determine the best routing paths among *K* candidate paths, by considering links' state, related costs and WCC. For the whole network, we must find the best strategy to route payload data and satisfy the greatest number of requests. Processing time of requests and paths selection are primordial to avoid network congestion and, consequently, minimize blocking probabilities of entering connections.

This paper presents two new algorithms for dynamic optical routing. Section 2.0 states the mathematical model considered. Section 3.0 describes the proposed algorithms. Section 4.0 presents and analyzes experimental results. A conclusion is presented in Section 5.0.

2.0 The Mathematical Model

Let us consider an optical network with *N* nodes and *M* links, one fiber per link and *W* wavelengths per fiber. The node and link locations are fixed and known. Each link has its own bandwidth, latency and cost. Connection requests arrive at each node following a Poisson process of mean value λ. The following model is a classical optical routing model we present in order to describe our objective function.

Let F_{ij}^{sdw} be the request arrived at the node *s* for the node *d* and which will be transmitted on link (*i,j*) by using wavelength *w.* Note that *i* and *j* belong to the set of nodes *N*.

The total number of requested calls accepted through the network after the simulation, using the wavelength *w* between *s* and *d*, will be γ_w^{sd}.

In this problem, we wish to maximize the utilization rate of each link (*i,j*) in the network:

$$\max_{ij} \sum_{sdw} F_{ij}^{sdw} \qquad (1)$$

subject to following constraints:

- $F_{ij}^{sdw} \in \{0, 1\}$; which means either the lightpath established for each request uses the wavelength *w* or not;
- $\sum_{s\in N} \sum_{d\in N-\{s\}} \sum_{w\in W} F_{ij}^{sdw} \le W$; which represents the capacity constraint on each link;
- $$\sum_{i} F_{ij}^{sdw} - \sum_{k} F_{jk}^{sdw} = \begin{cases} -\gamma_{sdw} & \text{if } s = j \\ \gamma_{sdw} & \text{if } d = j \\ 0 & \text{otherwise} \end{cases} ;$$

which is the WCC for each lightpath chosen.

The problem is solved by choosing the F_{ij}^{sdw}, depending on links' state. Then, our dynamic model uses this method applied step-by-step. By trying to resolve our objective function, we also help minimizing the number of blocked requests.

As formulated, this problem has been demonstrated NP-hard and is not solvable with standard mathematical approaches.

3.0 The Two Heuristic Algorithms Proposed

In order to simulate our algorithms, *K* candidate paths must be precomputed for each source-destination pair and we modify Yen's Algorithm [4], [6] to achieve suitable results over shorter time. Dijkstra's Algorithm is used to obtain the shortest path between two nodes.

Our two algorithms used the criteria of former algorithms such as LLR [5] and FPLC [1] to define new strategies. The first one, called Estimated Congestion Routing (ECR), is based on an estimate function of the congestion over links. The second algorithm, Hybrid Fixed-Paths Least Congested (HFPLC-k), is more rigorous with an exhaustive analysis of the resources available on the network.

A. Estimated Congestion Routing Algorithm

This algorithm uses two important helpful criteria to define congestion in an optical link: its cost that represents its liability and its relative importance in the network, and the current traffic on the link. The computation of the congestion degree for a link, at the arrival time of one request, uses the cost of this link over a whole path and the number of its free idle wavelength. It is expressed by:

$$DC_{(i,j)} = \frac{\sum_{(k,l)\in P} C_{(k,l)}}{C_{(i,j)}} * \frac{1}{\lambda^{free}_{(i,j)}} \qquad (2)$$

where $\lambda^{free}_{(i,j)}$ is the number of free wavelengths available on link (i,j), $C_{(k,l)}$ and $C_{(i,j)}$ represent the costs of links (k,l) and (i,j) respectively. So, the congestion degree of a path *P* with *l* hops is given by the mean value of congestion degrees computed on the links along P. The candidate path with the smallest degree of congestion will be selected to route the request's payload. After the route's selection, WCC is applied and if no wavelength is actually available, the request is blocked.

In a network of diameter H, the mean computational time complexity of ECR algorithm is $\boldsymbol{O(NKH^2W)}$. Indeed, each path cost is computed in linear time and, for each link on a mean length *H*-hops path, we calculate the degree of congestion by examining the *W* wavelengths of each link in the worst case scenario.

B. Hybrid Fixed-Paths Least Congested Routing Algorithm

This algorithm is inspired of FPLC-k routing algorithm. It adds a new criterion to the former algorithm by using the *k* most *congested links* of each path for evaluation, instead of the first *k* links of each path in FPLC-*k*. The additional criterion brings precious tuning to the routing algorithm that tends to avoid current and future congested paths. In this case, the more congested a link is, the less idle wavelengths it has. Continuous wavelengths available on the *k* most congested links of each path are counted and the path with the greatest number of continuous wavelengths is selected. After path selection, the WCC is verified and the request is blocked if ever no wavelength is common to all links of the selected path. The performance of the algorithm depends on the chosen number *k*, with *k* inferior to the mean diameter of the network.

Our routing algorithm is more balanced and its computational time complexity is $\boldsymbol{O(NKkH^2W)}$. Although HFPLC-*k* is more complex than the ECR algorithm, it considers the WCC during the selection path process by using only continuous wavelengths for the *k* links analyzed.

4.0 Experiments and Results

In this section, we introduce a few details regarding the implementation and the numerical results obtained with our algorithms. Node positions and characteristics are retrieved from a text file. Each pair of nodes is interconnected by unidirectional links. To simulate real networks in which link failure can occur sometimes, we choose to implement random link failures. In case of failure, path restoration is used, which means that new paths are found to retransmit former requests from paths affected by broken links. Call requests are generated dynamically in a text file and subsequently read as discrete events.

The initial number of *W* wavelengths per fiber for each link varies from 1 to 6. For each experiment cycle, we made 25 iterations, taking the mean value to represent final results. For each experiment, blocking rate and mean response time for each accepted call are measured.

Simulations are conducted on a ring network with 8 nodes interconnected by 16 links of single cost. Initial rate of arriving requests at each node is three per minute and link failure rate is set at 0.2% and the mean time of each simulation is fixed to 10 minutes. Parameter *k* is equal to 2 for FPLC-*k* and HFPLC-*k*. Blocking rate represents the number of blocked calls compared to the total number of call requests.

Table I shows the results obtained for each routing algorithm with *least used* or *spread* wavelength assignment [2], [3] and 3 wavelengths per fiber. ECR and HFPLC-2 generally yield the same results as well as LLR. In addition, we notice that the FPLC-2 algorithm has the worst results, regardless of the wavelength assignment method used. The particular network ring form implies that path length between two nodes can reach 7 hops. Thus, analyzing two links to select routes in this situation remains insufficient for FPLC-*2*. It requires greater value of *k* to give better results in this case. However, ECR gives the best overall results since it uses simple criteria to estimate the paths' congestion and it does not consider the WCC during the path selection process. Thus, the constraint relaxation during this process improves the set of feasible solutions and the estimation of congestion degree is more useful than an estimation based only on the number of free wavelengths available.

Number of requests per minute	Shortest Path	LLR	FPLC	ECR	HFPLC-2	FPLC-2
3	0.0598	0.0418	0.0371	0.0400	0.0413	0.0438
6	0.0832	0.0686	0.0684	0.0662	0.0695	0.0779
9	0.0969	0.0845	0.0802	0.0801	0.0834	0.0949
12	0.1311	0.1297	0.1248	0.1162	0.1302	0.1462
15	0.1410	0.1384	0.1363	0.1284	0.1398	0.1617
18	0.1549	0.1574	0.1541	0.1447	0.1558	0.1789
21	0.1817	0.1905	0.1851	0.1697	0.1928	0.2167
24	0.2091	0.2291	0.2241	0.2057	0.2294	0.2591
27	0.2164	0.2406	0.2367	0.2145	0.2399	0.2712
30	0.2272	0.2507	0.2439	0.2261	0.2501	0.2798
33	0.2378	0.2632	0.2592	0.2359	0.2633	0.2940
36	0.2563	0.2843	0.2826	0.2614	0.2862	0.3169

Table 1: Blocking Rates of Various Algorithms vs. Traffic Load

Also, measurement of the network mean response time presented in Table II shows that in fact, our algorithms require a little more time compared to others. For example, ECR had the highest response time due to amount of floating operations before path selection. Moreover, HFPLC-*2* consumes 10 to 50 milliseconds more than FPLC-*2*. However, FPLC appears to be the most efficient algorithm as it has low blocking rate with low response time. Thus, network operators could choose the most appropriate algorithm depending on which parameter is most important to them.

Number of requests per minute	Shortest Path	LLR	FPLC	ECR	HFPLC-2	FPLC-2
3	84.12	96.24	96.44	102.48	92.24	99.32
6	110.88	133.36	128.96	163.12	153.40	135.44
9	139.00	181.48	178.32	195.08	181.88	173.44
12	161.00	220.44	217.80	253.60	236.68	222.76
15	187.76	265.24	267.28	302.04	290.08	262.32
18	220.04	300.64	303.76	356.84	323.28	305.60
21	248.64	353.80	354.52	401.80	363.68	351.24
24	263.20	385.00	384.12	455.64	410.60	398.04
27	299.20	433.48	425.80	512.16	457.48	443.04
30	317.56	492.76	468.28	573.56	501.20	472.40
33	359.00	514.52	519.92	622.04	547.12	514.40
36	376.24	575.28	553.28	660.96	595.60	546.68

Table II:
Mean Response Time of Various Algorithms vs. Traffic Load

5.0 Conclusion

This paper presented two new routing algorithms proposed to solve the dynamic routing problem in all-optical networks. These algorithms are partially based on previous studies of former algorithms. Experimental results for ring topology show that we can improve former algorithms such as LLR routing. ECR algorithm produced the best results in ring topologies, whereas HFPLC-*k* remained stable versus FPLC-*k* for smallest values of k. Our two algorithms have higher response times due to floating operations costs for ECR and additional sorting of congested links in HFPLC-*k.*

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About the authors

Rolland Mêwanou is an engineer in Telematics and Network Science from École Polytechnique de Montreal. He also completed a master degree on dynamic routing problem in optical networks from the same university. He has been a research associate in LARIM (Mobile Computing and Networking Research Laboratory) and is now working as a software engineer for a mobile infrastructure software provider. His research fields include essentially the planning and designs of global telecommunication networks.

Dr. Samuel Pierre is currently a Professor of Computer Engineering at École Polytechnique de Montréal where he is Director of the Mobile Computing and Networking Research Laboratory (LARIM) and NSERC/Ericsson Industrial Research Chair in Next-generation Mobile Networking Systems. He is the author or co-author of 6 books, 15 book chapters, 16 edited books, as well as over 300 other technical publications including journal and proceedings papers. He is an EIC Fellow, senior member of IEEE and a member of ACM.

Letters to the Editor / *Lettres envoyées au rédacteur*

Subject: Date Standards

In the article on Software Development on p.16 of *IEEE Canadian Review* - Summer 2005, there is a statement "Software Engineering is a discipline that adopts engineering approaches, such as (...), standards, (...) seeking to result in (...) and measurable development schedule [14, 15]."

In this statement, "standards" are mentioned. I mention this because so much software fails the standards test when all-numeric dates are involved. We regularly see dates such as 4/1/2006 - will that be the fourth of January or April Fool's Day? And, all too often, software does not allow for the international (ISO 8601) standard format (in Canada, CSA/CAN3 Z234.4).

(...) It is time, I believe, that the issue of all-numeric date standards be taken seriously - especially by engineers and engineering schools.

D.T. Bath, Peterborough, ON

Editors' Response

Dear Mr. Bath:

The *IEEE Canadian Review*'s Managing Co-Editors share your concern for the (reasonable) use of appropriate dates standard. As much as possible, when full numeric dates are used, we will keep an eye on using unambiguous notation such as yyyy-mm-dd. Of course, rigorous standards such as ISO and CSA/CAN3 relevant ones should be used for technical works where such precision is warranted.

Managing Editors

Readers are invited to comment on material published in the **IEEE Canadian Review** *and on matters of interest to engineering and technology professionals. Letters do not represent the opinion of the IEEE. They may be edited for space and clarity. Email: e.holdrinet@ieee.org*

IEEE Fellows Awards
2006 newly-elected Fellows from Region 07

IEEE Canada

The IEEE Fellow Committee has named 271 Senior Members to Fellow Grade, effective January 1st, 2006. The number of new Canadian Fellows is quite impressive at 15, in proportion to our total membership in the organisation, and the Review is proud to number one of its past Managing Editors amongst them. Sincere congratulations to our eminent new Fellows.

Prof. Jorge Angeles McGill University Montreal, Quebec *For contributions to the kinematics, dynamics and design of robotic mechanical systems.*	**Dr. Tongwen Chen** University of Alberta Edmonton, Alberta *For contributions to sampled-data control and multirate systems.*	**Dr. James Dymond** General Electric Canada Hammonds Plains, Nova Scotia *For contributions to the analysis, design, optimization, testing and application of large AC Machines.*
Dr. George Eleftheriades University of Toronto Toronto, Ontario *For contributions to conception, analysis and fabrication of electromagnetic materials and their applications.*	**Prof. Alex Gershman** McMaster University Hamilton, Ontario *For contributions to adaptive beamforming and sensor array processing.*	**Prof. Andre Ivanov** University of British Columbia Vancouver, British Columbia *For contributions to infrastructure intellectual property (IP) for system on a chip (SoC) testing.*
Prof. Geza Joos McGill University Montreal, Quebec *For contributions to the theory and application of high power converters in power systems.*	**Prof. Frank Kschischang** University of Toronto Toronto, Ontario *For contributions to trellis structures, graphical models and iterative decoding techniques for error-correcting codes.*	**Dr. Ellsworth LeDrew** University of Waterloo Waterloo, Ontario *For contributions to environmental remote sensing sciences.*
William Lockley Lockley Engineering Calgary, Alberta *For leadership in the development and application of large electric drive systems for gas compression.*	**Dr. Douglas O'Shaughnessy** INRS-EMT Université du Québec Montréal, Québec *For contributions to education in speech processing and communication.*	**Dr. Resve Saleh** University of British Columbia Vancouver, BC *For contributions to mixed-signal integrated circuit simulation and design verification.*
Dr. Vijay Sood Hydro-Québec (IREQ) Varennes, Québec *For contributions to modeling and simulation of high voltage DC (HVDC) transmission systems and controllers.*	**Dr. Dennis Woodford** Electranix Corporation Winnipeg, Manitoba *For leadership in the development of digital simulation of DC links and flexible AC transmission devices.*	**Dr. Qi-jun Zhang** Carleton University Ottawa, Ontario *For contributions to linear and nonlinear microwave modeling and circuit optimization.*

Complete list of IEEE Fellows 2006 at http://www.ieee.org/fellows

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IEEE Canada

CCGEI 2006

La technologie pour un monde meilleur

Conférence Canadienne de génie électrique et informatique

7 au 10 mai 2006, Centre des Congrès d'Ottawa, Canada

http://ieee.ca/ccece06/

APPEL DE SOUMISSION D'ARTICLES

La conférence canadienne de génie électrique et informatique 2006 de l'IEEE offre un tribune pour la présentation de travaux de recherche et de développement en génie électrique ou informatique provenant du Canada et du monde. Des communications en français ou en anglais sont sollicitées sur des sujets qui incluent, mais ne sont pas restreints à ceux mentionnés ci-dessous :

- Architectures avancées d'ordinateurs
- Electronique analogique et numérique
- Intelligence artificielle
- Réseaux et systèmes informatiques
- Théorie du Contrôle et applications
- Traitement numérique des signaux
- Circuits, Systèmes et ITGE
- Interaction human-machine
- Traitment de l'image et de la parole
- Instrumentation et mesure
- MEMS et Nanotechnologie
- Réseaux neuronaux et logique floue
- Reconnaissance de formes
- Fiabilité des systèmes de puissance
- Systèmes d'exploitation en temps réel
- Micro-ondes et RF
- Télédétection, capteurs et dispositifs
- Apprentissage, affaires, et commerce électronique
- EMC & EMI
- Systèmes à base d'agents et sur Internet
- Eléctromagnétisme et antennes
- Génie biomédical et bioinformatique
- Communications et systèmes sans fil
- Bases et exploration de données
- Machines et entraînements électriques
- Ingénierie de haute tension
- Calculs de haute performance
- Systèmes intelligents
- Microélectronique et optoélectronique
- Informatique mobile
- Systèmes optiques et photoniques
- Électronique de puissance
- Robotique et mécatronique
- Sécurité, confidentialité et fiabilité
- Génie logiciel
- Production d'énergie et énergies renouvelables
- Réalité virtuelle et Nouveaux médias

1.0 Soumission d'articles

Veuillez soumettre électroniquement un résumé de votre article, d'environ 300 mots, au site web:

http://ieee.ca/ccece06 au plus tard le décembre 2005.

2.0 Soumission de propositions pour organiser des sessions spéciales

Pour soumettre une proposition visant à organiser une session spéciale, veuillez contacter Dr. Voicu Groza (vgroza@ieee.org), au plus tard le 4 décembre 2005.

3.0 Soumission d'ateliers et de tutoriels

Pour soumettre une proposition visant à offrir ou à organiser un atelier ou un tutoriel, veuillez contacter Mr. George Yee (g.m.yee@ieee.org), au plus tard le 20 janvier 2006.

4.0 Compétition de catégorie étudiante

Si l'auteur principal d'un article soumis à la conférence est un étudiant, cet article sera inclus automatiquement dans la compétition de catégorie étudiante.

5.0 Dates limites à noter

Soumission de résumés d'articles:.....le dimanche, 4 décembre 2005

Soumission de propositions pour sessions spéciales: .....le dimanche, 4 décembre 2005

Soumission d'ateliers et tutoriels: .....le vendredi, 20 janvier 2006

Notification d'acceptation d'un article: .....le dimanche, 5 février 2006

Version finale d'un article et enregistrement d'auteurs: ..... le vendredi, 24 février 2006

6.0 Expositions

Pour louer un espace d'exposition, veuillez contacter le président du comité organizateur de cette activité, Dr. Jasmin Roy (jasmin.roy@crc.ca), au plus tard le 7 avril 2006.

CCECE 2006 - CCGEI 2006
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IEEE Canada

CCECE 2006

Technology for a Better World

19th Annual Canadian Conference on Electrical and Computer Engineering

May 7 - 10, 2006, Ottawa Congress Centre, Ottawa, Canada

http://ieee.ca/ccece06/

CALL FOR PAPERS

The 2006 IEEE Canadian Conference on Electrical and Computer Engineering provides a forum for the presentation of electrical and computer engineering research and development from Canada and around the world. Papers are invited, in French or English, including but not limited to the following topics:

- Advanced Computer Architecture
- Analog & Digital Electronics
- Artificial Intelligence
- Computer Networks & System
- Control Theory & Applications
- Digital Signal Processing
- Electronic Circuit and VLSI
- Human-Machine Interactions
- Image & Speech Processing
- Instrumentation & Measurement
- MEMS & Nanotechnology
- Neural Networks & Fuzzy Logic
- Pattern Recognition
- Power Systems Reliability
- Real-Time Embedded Systems
- RF & Microwaves
- Remote Sensing, Sensors and Devices
- E-Learning, E-Commerce, E-Business
- EMC & EMI
- Agent-Based & Internet-Based Systems
- Electromagnetics & Antennas
- Biomedical Engineering & Bioinformatics
- Communications & Wireless Systems
- Database & Data Mining
- Electrical Machines & Drives
- HV Engineering
- High-Performance Computing
- Intelligent Systems
- Microelectronics & Optoelectronics
- Mobile & Pervasive Computing
- Optical Systems & Photonics
- Power Electronics
- Robotic & Mechatronics
- Security, Privacy & Trust
- Software Engineering
- Power systems & renewable Energy
- Virtual Reality and New Media

1.0 Regular Paper Submission:

Please submit a 300-word abstract of your paper to the Technical Program Committee using the on-line submission process on our web site at http://ieee.ca/ccece06 before December 4th., 2005.

2.0 Special Sessions Proposal Submission:

Proposals for special sessions must be received by December 4th., 2005. Please contact the Technical Program Co-Chair at vgroza@ieee.org

3.0 Workshop and Tutorial Submission:

Workshop and tutorial proposals must be received by January 20th, 2006. Please contact the Workshop / Tutorial Chair at g.m.yee@ieee.org

4.0 Student Paper Competition:

If the first author of a paper submitted to the conference is a student, that paper will be automatically considered for Student Paper Competition.

5.0 Important Dates

Paper abstracts must be received by: ..... Sunday, December 4th, 2005
Special Session proposals must be received by: ..... Sunday, December 4th, 2005
Tutorial / workshop proposals must be received by: .....Friday, January 20th, 2006
Notification of acceptance will be sent out by: ..... Sunday, February 5th, 2006
Final papers and author registration must be received by: .....Friday, February 24th, 2006

6.0 Industrial Exhibits

To rent exhibit space at the conference, please contact the Sponsorship / Exhibition Chair Dr. Jasmin Roy at: jasmin.roy@crc.ca before April 7th, 2006.