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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:

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Quelques mots du rédacteur en chef

Vijay K. Sood, Hydro-Québec

Cette époque de l'année est très chargée pour moi comme le printemps s'approche et qu'il y a le CR à finaliser et les rapports d'impôt à préparer. Chaque année, je dois traverser cette dure période tout en me disant qu'il doit bien exister une façon plus facile pour y arriver. Si vous en avez une à me proposer, merci de me le faire savoir. Le logiciel pour faire les rapports d'impôt qui est disponible sur le marché s'est amélioré et aide à accélerer le processus. Mais je me demande alors, pourquoi doit-on faire cela pour aider le(s) gouvernement(s) et entrer les données à leur place afin de nous taxer? Si le gouvernement se permettait de nous envoyer le logiciel pour faire leur travail, je pourrais comprendre. Il est dans l'intéret du gouvernement, alors pourquoi ne peuvent-ils pas acheter le logiciel et le donner aux contribuables. Ils avaient l'habitude de nous envoyer les formulaires de rapport d'impôt (depuis quand les rapports écrits sur du papier sont la norme?). Rappellez-vous que le prix du logiciel de rapports d'impôt est d'environ 35-40$, quand les particuliers l'achètent. Si le gouvernement l'achetait (comme un service public), celà coûterait moins globalement. Aucun emballage ne serait requis pour la vente dans les magasins. Nous, les utilisateurs, n'aurions juste qu'à le télécharger de l'Internet. Les améliorations seraient disponibles immédiatement au lieu de retourner voir le programmeur. Est-ce que le coût relié à cette alternative serait plus important que le coût relié à l'alternative des formulaires papier? Je suis sûr qu'ils doivent avoir plutôt d'autres projets.

Les nouvelles provenant de l'industrie sont encourageantes comme le taux de chômage diminue. Après les évènements de l'année dernière, le ciel n'est pas tombé sur la tête et les gens retournent à leur routine quotidienne. J'espère que la tendance va se maintenir et que ce type d'évènement ne se reproduira plus.

Cette édition du CR est un peu plus petite avec 28 pages, mais elle contient un ensemble d'articles intéressants. J'espère que vous allez les aprecier. Vos commentaires et vos suggestions sont toujours les bienvenues.

Joyeux printemps, et ne vous laissez pas piquer par les moustiques.

Cover picture / *Photo de couverture*

The photograph shows the 5.28 MW North Cape Wind Plant and wind test facilities of Atlantic Wind Test Site Inc. (AWTS), located at North Cape, the northernmost tip of Prince Edward Island.

Commissioned in Nov. 2001, the North Cape Wind Plant, in its first phase, has eight V47 - 660 kW variable slip wind turbines supplied by Vestas, Denmark. The North Cape Wind Plant was developed and constructed by the PEI Energy Corporation on property adjacent to the Atlantic Wind Test Site. Atlantic Wind Test Site Inc. is a national facility for testing and developing wind energy technologies and has been a key participant in Canadian wind energy. Its wind test and development facilities include horizontal axis wind turbines (Vergnet Canada's 25 kW, AOC 50 kW, Windmatic 65 kW, Lagerwey 80 kW), vertical axis wind turbines, and comprehensive wind-diesel test facilities. The Test Facility for Wind and Solar Energy Conversion System of the University of New Brunswick is also located at AWTS.

A few words from the Managing Editor

This is a particularly busy time of the year for me as spring is in the air, and there is the CR to finish and the taxes to be done. Every year I go through this agony, and say to myself, there must be an easier way to do this. If you figure it out, let me know. The tax software on the market is getting better, and helps to speed up the process. But then, I ask myself, why are we doing this to help the government(s) and enter the data for them to tax us? If the government was willing to send us the software for doing their job, I might understand. It is in the government's interest, so why cannot they purchase the software and give it out to the taxpayers. They used to give us the tax forms (when the paper returns were the norm)? Remember, the cost of the tax software is about 35-40$, when individuals buy it. If the government bought it (as a public service), it would cost a whole lot less. No packaging would be needed for sale in the shops. We, the public would just download it from the internet. Any updates would be available immediately, instead of having to go back to the software developer. Is the cost of this going to be any more than a paper tax form? The tax software developers may complain, but then so what? I am sure they have other projects to go for.

The news from industry seems to be brightening as the jobless rate is declining. After the events of last year, the sky has not fallen down and people are getting back to their daily routines. I hope that the trend continues and we can put this behind us.

This edition of the CR is a little thinner at 28 pages, but we do have an interesting set of articles for you. I hope that you will enjoy them and find them informative. Your comments and input are always welcome.

Have a great springtime. And don't let the mosquitoes bite.

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MONTRÉAL, Feb. 25, 2002. CMC Electronique a obtenu un contrat pour la fourniture de son système de commande et de visualisation multifonctions destiné au programme de modernisation des avions de type Tornado des Forces armées allemandes. Le système de commande et de visualisation multifonctions comprends notamment les capteurs et les radios de navigation, les radiocommunications, les afficheurs et du matériel avionique de mission ainsi que le matériel avionique d'aéronef, permettant une réduction de la charge de travail du pilote. Le dispositif possiblement installé sur plus de 300 appareils permettraient de générer à la compagnie des revenus de 20 millions de $.

TOKYO, JP, Nov. 20, 2001. VoiceAge Corporation, which has its corporate headquarters in Montréal (QC), launched a 3G-compatible multimedia content creation software. SPOTxde(TM) will enable the providing of multimedia content ultimately to handled users. The software is based on the industry standards such as 3GPP Adaptative Multirate Narrowband for voice compression and MPEG4 for video compression.

MONTRÉAL, QC, le 26 nov. 2001. L'Hôpital Listowel Memorial Hospital (LMH) a confié à la compagnie Purkinje l'implémentation d'un système informatique implémentant un dossier patient électronique. Ce dernier permettra l'intégration des informations cliniques nécessaires au suivi du dossier d'un patient et notamment les diagnostics. Dans un second temps, après juin 2002, l'implémentation du dossier patient électronique permettra au personnel autorisé , autre que les médecins et le personnel infirmier de l'urgence, d'avoir accès à l'information pertinente.

OTTAWA, Dec. 13, 2001. Societe des Alcools du Quebec (SAQ) choose Cognos Analytic Applications which will be used together with J.D. Edwards for optimizing the performance of the company. The SAQ comprises 379 retails branches, 303 agencies and 9200 store outlets. The SAQ handles 29 million transactions per year.

OTTAWA, Jan. 21, 2002. Entrust Inc will be used by the Royal Canadian Mounted Police (RCMP) to share information between police forces all over Canada. Sharing sensitive intelligence information will help fighting organized crime and ongoing police operations. About 75000 users will be Entrust "certified" among the RCMP, the municipal and the provincial police forces once the deployment is completed.

VANCOUVER, Feb. 12, 2002. A web-based education portal was developped by Briyante Software Corp in partnership with Alberta Learning and the Calgary Board of Education (CBE). Teachers will be able to find on this portal lesson plans from kindergarden to grade 12. The portal will also comprise newsgroups, searching engines, etc and will be also be available to students as well as parents.

BRAMPTON, ON, Mar. 12, 2002. Famous Canadarm captured Hubble Space Telescope and redeployed it successfully during space mission STS-109. This is the fourth servicing mission for the Canadarm on the Hubble Space Telescope for a total of 18 spacewalks.

TORONTO, ON, Nov. 19, 2001. Air Canada Regional Inc, owned by Air Canada, will receive training services by CAE under a ten-year agreement. The training services will comprise the delivering of two Dash 8-100/300 simulators. The two simulators will be in operation at beginning 2003, one will be located in Ontaria while the second one will be located in western Canada. Air Canada Regional employs 1500 pilots.

TORONTO, ON, le 11 Déc. 2001. QNX a développé un progiciel (MOST) permettant le développement rapide d'applications intératives multimédias pour le système d'exploitation "temps-réel" QNX. Ce progiciel cible notamment les constructeurs automobiles; il permettra d'implémenter des dispositifs de divertissement embarqués, des tableaux de bord exploitables sur le web, l'interfacage de dispositifs DVD et CD-ROM, la commande vocale, les dispositifs de communication cellulaires, etc. Un réseau de fibre optique est optimalement utilisé avec ces applications afin de permettre un taux de transfert d'information adéquat.

TORONTO, ON, Jan. 7, 2002. Mount Sinai Hospital (MSH) is now a place where handhelds are widely used by healthcare professionals. Palm handhelds are now used by healthcare professionals to provide up-to-date medical informations to physicians. The handhelds are also used to monitor and log educational experiences of surgical interns and medical trainees. A mobile drug database is also available. Furthermore trainees are now supervised using data they transfer using their handheld on a central server.

OTTAWA, ON, Jan. 10, 2002. Internic.ca is now the first company to offer back-order service on .ca domain name in Canada. A user may choose to be informed when a certain .ca domain name will expire and place an order.

MISSISSAUGA, ON, 28 Mar. 2002. Cybersecure Inc fait partie des 10 compagnies selectionnées par Microsoft en matière de sécurité. Ces compagnies selectionnées doivent démontrer un haut degré en matière de solutions de sécurité sur la plate-forme Microsoft.

A critical survey of protocols proposed by the IETF as enablers for customer interaction in an electronic customer relationship management system -- Part I - eCRM metrics

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Abstract

A modern enterprise needs to interact with customers anytime, anyhow and anywhere to be successful in the global marketplace. This level of customer interaction has become possible due to the advancements in network infrastructure and the simultaneous development of voice and multimedia protocols for seamless transport of information. Instant and unified messaging extends this capability to enable customer touch point integration. This paper provides a critical analysis of the metrics of an effective electronic customer relationship management (eCRM) customer interaction system from customer, business and technology viewpoints. Based on this analysis, Part II of this paper will review the features and the services offered by some of the protocols as proposed by the Internet Engineering Task Force (IETF) with respect to their effectiveness in enabling customer interaction, and derive an IETF based protocol suite that may be used in an eCRM system.

Sommaire

Une entreprise moderne doit interagir avec les clients à tout moment et à tout endroit afin de réussir dans le marché global. Ce niveau d'interaction avec les clients est rendu possible grâce aux avancées dans les infrastructures des réseaux et dans le développement simultané de protocoles pour la voix et le multimédia afin de transporter sans soucis l'information. La messagerie instantanée et unifiée étend cette capacité à rejoindre le client. Cet article présente une analyse critique des éléments d'un système efficace de gestion des relations avec les clients (eCRM) sous l'angle de vue client, affaire et technologique. Basée sur cette analyse, la seconde partie de cet article va revoir les caractéristiques et les services offerts par certains des protocoles offerts par l'Internet Engineering Task Force (IETF) et particulièrement les caractéristiques qui sont en rapport avec l'efficacité et déterminer une suite de protocoles basée sur un protocole de l'IETF et qui pourrait être utilisée pour un système de type eCRM.

1.0 Introduction

Today most e-businesses implement eCRM by using human-computer interaction and thereby reduce the need for human intermediaries [1]. CRM entails four phases:

- Customer interaction,
- Data analysis and mining,
- Knowledge discovery, and
- Market planning [2].

Electronic customer interaction involves encouraging the customer to spend time electronically in order to obtain sufficient information regarding the customers needs, preferences and requirements. This information is analyzed using a process such as data mining to extract knowledge about customer values. Customer values are, in turn, used as the guiding principle in the market-planning phase to customize and personalize the services/goods/sales offered by the enterprise. An integrated approach to eCRM is important because it can be effectively used to analyze information for continuous, online and real-time learning of customer values. This paper focuses primarily on key technology issues and, to a lesser extent, on business and customer centric issues. We first identify what factors (metrics) are valuable in an eCRM system from the point of view of the various stakeholders and associate a priority level (critical, important, and desirable) with each metric. As shown in Figure 1, the three stakeholders typically identified in an eCRM framework are the customer, the business enterprise and the provider of technology [2].

Section 2 of this paper, discusses customer interaction requirements in an eCRM system. Section 3 identifies the metrics first from a customer centric perspective that may be used to evaluate what a customer expects when interacting with a voice/multimedia enabled eCRM system. Section 3.2 identifies the key metrics an enterprise may wish to evaluate before adopting or integrating a given protocol or technology with existing legacy eCRM systems. This will help an enterprise decide what technology is relevant to it and how much of it? It will also help an enterprise understand what is the potential of a particular technology or protocol. Section 3.3 identifies a series of requirements (metrics) from a technology perspective that would enable eCRM and how each requirement may influence its adoption by an enterprise for effective interaction with the customer. Section 4 has a critical analysis of the metrics from the three stakeholders perspective and categorizes them into mutually exhaustive, mutually exclusive and non-overlapping requirements. Based on these metrics, Part II of this paper will review

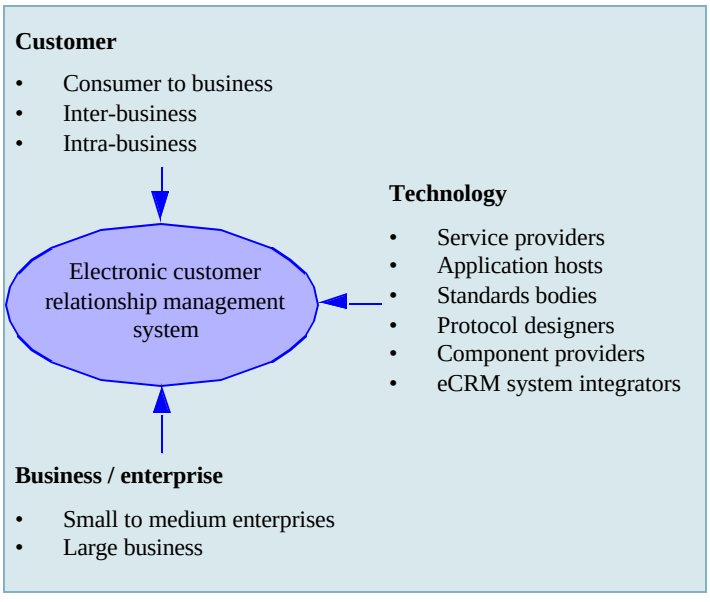

Figure 1: Stakeholders in an electronic CRM system

the features and the services offered by some of the protocols as proposed by the Internet Engineering Task Force (IETF) with respect to their effectiveness in enabling customer interaction, and derives an IETF based protocol suite that may be used in an eCRM system [8].

2.0 Customer interaction requirements in an eCRM system

Good CRM must begin with effective, real-time, reliable and secure customer interaction. All other steps in the eCRM process rely on this most important first customer interaction phase. Customer interaction is said to be successful if it is two-way, integrated, recorded and managed [2]. Customer interaction is integrated when it is coordinated across all customer touch points which include email, voice mail, public switched telephone network (PSTN), website and fax. This may be implemented using an integrated communications system and needs to be in real-time to be effective. Call centres with automatic call routing capabilities are an additional asset in routing a call from a customer to an appropriate representative within the least possible time [3]. Management of the two-way interaction involves customizing and personalizing of the interaction and the associated communication channel. Tailoring the response to the requirement of various customer segments can customize the interaction. The interaction can be personalized further by tailoring the system response to the needs of a particular customer, thereby enabling one-one relationships. The communication channel can be personalized by specifying caller preferences and by ascertaining callee capabilities. Doing this would have benefits in terms of assuring quality of service (QoS) or alternately, on a best effort basis, in allocating network resources for the call and ensuring real (near real) time delivery (receipt) of information to (from) the customer.

3.0 Analysis through metrics

With the e-business eCRM requirements for ensuring successful customer interaction in mind, proposed in the following sections are a number of metrics that a customer may use to evaluate the responsiveness of an eCRM system. The enterprise or business may use the customer centric metrics to measure the effectiveness of the system for first time customer interaction and to encourage repeat interaction with the system. The customer centric metrics for evaluating the responsiveness of an eCRM system form the basis for deriving the business centric metrics for adopting a particular protocol or technology. The technology centric metrics can be broadly classified into protocol and architecture, infrastructure, engineering and service metrics.

3.1 Customer centric metrics for measuring the performance of an eCRM system

The most important measure that a customer will use for repeat interaction with an eCRM system of an enterprise is the ease of using such a system. Customers are also concerned with privacy issues when they are asked to reveal information, sensitive or otherwise. Reassuring a customer about the nature of the information being collected, why it is being collected and how it may be used is very important. It is also advisable to assure the customer regarding the security measures such as, authentication, encryption, authorization and other measures that are in place to ensure the customer's right to privacy. It is important that the communication channel characteristics, protocol and technology are designed for real time applications. Whatever may be the nature of technology and protocols used in the eCRM system, they must be transparent to the customer i.e., the customer need not have any knowledge regarding the capabilities and technical characteristics of the various components of the system. Also, the eCRM system must be capable of integrating multiple customer touch points such as email, fax, or telephone. If the customer cannot obtain a satisfactory response from the eCRM system, it must be possible for the customer to locate automatically an appropriate customer service representative in a reasonable period of time. Given below are the customer centric metrics that can be used in designing an eCRM system and their associated priority level to the customer.

- **Ease, convenience and availability**
  - Contact the enterprise at anytime - critical
  - Ease of use - critical
  - Speed of transaction and real-time/near real-time perception – important
  - Customer touch point integration – important
  - Accessibility through wireless communication devices - important
  - Ease in locating a customer representative – desirable
  - Customer friendly technology - desirable
- **Guaranteed privacy - Critical**
  - Secure communication - critical
  - Prevention of security threats - critical
- **Other features**
  - Customizing the communication channel - Desirable
    - Capability in specifying user/caller preferences
    - Interrogating the system to obtain callee capabilities
  - Collating information - Desirable
- **Annoyance factors that need to be eliminated/reduced**
  - Non-real time perception in voice communication

Table 1: Impact of customer centric metrics on business centric objectives.

Customer Centric Metric	Interaction	Gather information (I) and formulate knowledge (K)	Customizing responses	Personalized responses
Convenience	Critical			
Ease of use	Critical			
Privacy and security	Critical	Critical (I)	Critical	
Real time perception	Important	Critical (I)	Critical	Critical
Customer touch point integration	Important	Critical (I)		Critical
Integrated communication	Important		Critical	
Automatic call routing	Desirable			Critical
Friendly technology	Desirable			Critical
Customize communication channel	Desirable		Critical	
Collate information	Desirable	Critical (K)		Critical

- Intrusiveness
- Repetition of information gathered from the customer by the system
- Lack of human interaction
- Excessive hold times – especially excessive delays in obtaining information from the system

This approach will be used in deriving the business centric metrics used for adopting an effective eCRM system.

3.2 Business centric metrics for adopting a performance effective eCRM system

Figure 2 shows the key business centric objectives required to attract, retain and increase customers.

Table 1 summarizes the relative importance of customer centric metrics in relation to business. From the customer viewpoint, convenience of communicating with the enterprise is critical and must be available all the time. The ease in using an eCRM system is a function of system design and is determined by several factors such as its accessibility, reliability of system, help available on line, whether it implements integrating customer touch points, the number of simultaneous users that the system can support, the responsiveness of the system and the appropriateness of system response to queries. Secure communication i.e., prevention of security threats such as stalking, spoofing and spamming is essential to addressing the security and privacy concerns of the customer. In addition, the communication itself may be encrypted to ensure secrecy. Real-time perception on the part of the customer is directly related to the bandwidth of the communication channel, system latency, delays related with Internet traffic, packetization, and access [4]. System latency is associated with the various technologies employed such as codecs (coder/decoder), echo canceller (in voice transmission), transforming voice, fax, and video at both customer and enterprise ends. Delays are related to packetization before transmission and buffer, modem processing at the customer end. In addition, there is internet delay associated with the internetwork infrastructure such as ISPs or PSTN that is used in communications with the customer. Access delay is encountered at various servers, gateways and access points in the enterprise, and the PC processor and OS architectures employed at the enterprise and customer ends.

Customer touch point integration involves integrating communication across service providers (PSTN, ISP), across devices (computer, fax, phone) and across services (email, voice mail, instant messaging). Towards integrated communication, mobile commerce is an issue most enterprises will have to address in their evolution from purely click and mortar enterprises to ones that also support interaction with mobile customers. An issue to be addressed in the adoption of a protocol or technology is whether the same protocol/ technology can be adopted/ adapted in a mobile scenario. Thus, from a business perspective, an enterprise needs to balance the conflicting metric of finding a cost effective eCRM solution with customer satisfaction. Availability of off-the-shelf components is a prerequisite to lowering the cost of the eCRM system, as the enterprise need not bear the expenses of development. Also, a protocol or technology must be developed with backward compatibility in mind i.e., it is operable with existing legacy systems such as existing fax, voice, phone and email systems. Customer service representatives must have an understanding of the various components of the

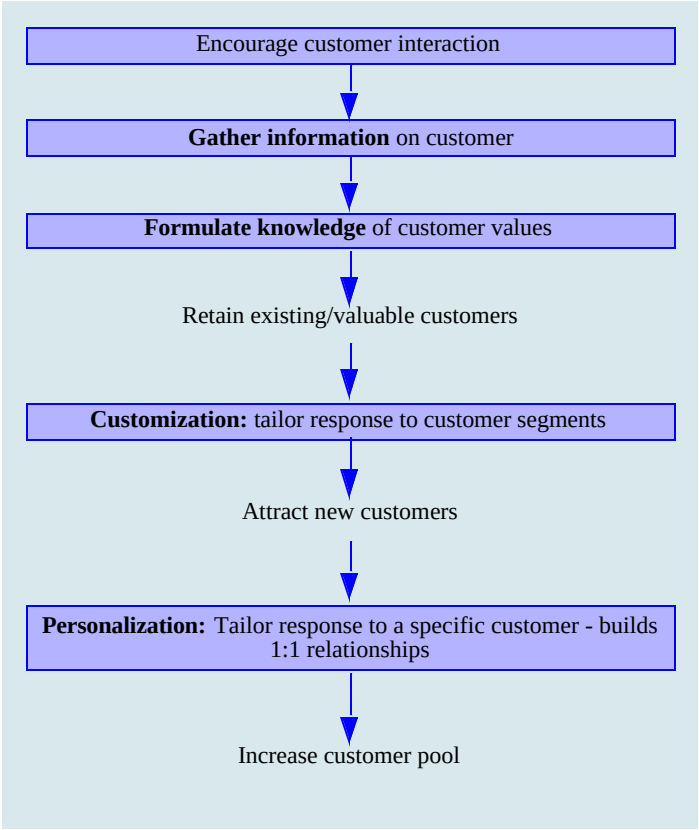

Figure 2: Business centric-objectives in attracting, retaining and increasing customers

Table 2: Mutually exhaustive eCRM metrics from the stakeholders perspective

Customer centric	Business centric	Technology centric
Contact enterprise at any time, and easy to use	High accessibility, reliable operation and support for multiple users	Protocols that initiate and maintain multi-media communication over IP or over legacy PSTN. The communication may be in real-time or may be non-real time integrated (PSTN or internet based) messaging.
Real time perception - Speed of transaction	eCRM system responsiveness: • delay and latency • QoS, bandwidth	Protocols must address packetization delay. eCRM architecture (servers, gateways, access points) introduce processing delay. System latency is associated with technology employed (e.g., A-D converters). Enterprise network architecture and protocols used must support QoS.
Can reach enterprise through • any service • any device	Customer touch point integration Integrate wireline and wireless devices	Integrate legacy PSTN services with Internet based services, ensure interoperability of heterogeneous mail and messaging systems (such as voice mail, email, video), Integrated instant messaging. Extensibility of wireline protocols and service models to wireless protocols/services.
Privacy • Sensitive • Non sensitive	Security – prevent security threats Encryption of communication and protect customers privacy	Prevent stalking, spamming and spoofing, Support authentication, authorization, non-repudiation and encryption standards.
Ease in locating customer service representative	Automatic call routing	Integrate web based and phone based access systems.

Table 3: Mutually exclusive eCRM metrics from the stakeholders perspective

Customer centric	Business centric	Technology centric
	Low cost of broadband infrastructure	High bandwidth
Fast, appropriate response	Low overall processing time for eCRM system	

eCRM system, their capabilities and deficiencies for a better appreciation of the role of the eCRM system in the enterprise. This will help towards achieving better employee acceptance of the new technology.

Summarized below are the various business centric metrics in order of importance in assessing the effectiveness of an eCRM system.

- **eCRM system design metrics**
  - High accessibility - Critical
  - Reliable operation - Critical
  - Mobility issues - i.e., adoptability/adaptability of the protocols/technology in a mobile scenario. - Desirable
  - Tutoring customers to technology requirements of the eCRM system with appropriate help menus - Important
  - Simultaneous servicing of multiple customers - Critical
- **Responsiveness of the system**
  - Delay and latency issues - Critical
  - Quality of service - Important
  - Bandwidth requirement - Important
- **Security and privacy**
  - Encryption of communication - Critical
  - Prevention of security threats i.e., stalking, spoofing, and spamming - Critical
- **Cost reduction - Critical**
  - Availability of off the shelf equipment/components/protocols that can interoperate and work together - Important
  - Interoperability with existing legacy systems - Important
- **Employee acceptance - Important**

3.3 Technology centric metrics that enable an effective eCRM system

Technology centric requirements can be broadly classified into the following classes, protocol and architecture, infrastructure, engineering and service [5,6]. The protocols deal with the rules for the implementation of orderly multi-media communication within the eCRM system. The architectural viewpoint describes the functions needed of the various logical modules that together implement the features of each protocol, communication channel and interactions between the various modules. The infrastructure or technology deals with the hardware/firmware components with which the eCRM system is designed, including protocol stacks, implementation languages, operation systems and physical equipment. Service requirements deal with the functional requirements expected or offered by the various logical modules in the eCRM system.

3.3.1. Protocol and architecture metrics:

Protocol and architecture metrics encompass interoperability, latency, wireline vs. wireless, security features, QoS provisioning, and packet delay. The standards bodies such as ITU and the IETF workgroups propose their own versions of protocols for achieving similar goals. For example, signalling and managing multimedia communication sessions can be achieved either by adopting the H.323 protocol as proposed by the ITU or SIP proposed by the IETF [4]. A key issue is then, whether equipment that conforms to one standard can interoperate with equipment conforming to the other standard. In addition, the latency associated with a protocol is implementation-dependent i.e., various implementations by different vendors of the same protocol may have varying latency associated with them. Typically, protocols are designed either for use on wired media or wireless media. This is an issue when an enterprise may wish to migrate from supporting wired eCRM to an integrated system supporting both wired and wireless communication. Various protocols address security issues to varying extents. Security issues include whether authentication and non-repudiation is required, when to use authorization, and what encryption standard is used. Protocol extensibility is an important issue in that a client (enterprise or service provider) may propose extensions to the protocol for provisioning custom services.

Architecture metrics deal with the functionality of the various components of the eCRM system, and modularity. The architecture must address the issue whether different components can be added in a modular fashion to achieve a new functionality. A protocol is typically associated with its own architecture. The architecture is typically implemented as a set of logical modules or entities, with a specific functionality associated with each module. The protocol can then be implemented by combining the functions of one or more logical entities into the same box. This approach has advantages in that additional functionality can be added by incorporating new logical entities where the functionality of each entity is clearly defined. Features such as security and QoS provisioning can now be addressed in a modular framework with an entity assigned the task of ensuring security levels and provisioning QoS before communication is established [7].

3.3.2. Infrastructure metrics – enterprise:

The infrastructure metrics that an enterprise must concern itself with when implementing an eCRM system include core network technology, the QoS model, and the interoperability of the eCRM infrastructure with existing legacy systems. The choice of core network technology and its architecture impacts bandwidth utilization, and hence, the latency and delay experienced by the customer. The IETF QoS framework may be broadly classified into two classes, an integrated service (*intserv*) model

Table 4: Non-overlapping metrics from the stakeholders perspective

Customer centric	Business centric	Technology centric
Transparency – the customer is (may) not (be) interested in the details of the technology/ protocols	Tutor customers on how to use the eCRM system effectively	
	Employee acceptance of eCRM system	Ease in incorporating additional functionality
		Provision to tailor services to the needs of the enterprise

and a differentiated (*diffserv*) model [7]. The *intserv* model is based on the premise that resources such as bandwidth and buffer allocation are managed for each real time application. It also provides a guaranteed service, a best effort service or an enhanced best-effort service end-to-end. On the other hand, the *diffserv* service is based on requesting a specific performance level for each packet on a per hop basis. The *diffserv* model can be either quantitative, in which the performance of parameters such as throughput, delay, jitter and packet loss is specified in deterministic or statistically quantitative, or priority based, in which the each packet has a priority assigned to it in accessing a given service.

3.3.3.System Integration metrics:

eCRM system integration must meet metrics such as, the interoperability of various subsystems from different vendors, and the conversion of heterogeneous messages such as video, voice, text, email etc. into standard formats to support unified messaging. Also, the eCRM system must be implemented with minimal duplication and must support number portability specifically, service and service provider portability.

3.3.4.Engineering and Service metrics:

Engineering metrics include the use of codecs (coder/decoder) and echo cancellers for voice conversion before transmission and may include speech to text conversion for storing customer interaction data to be used for data mining and possible knowledge discovery purposes. The issue of backward compatibility, i.e., the question whether devices designed for the current environment can inter-operate consistently with legacy systems must be addressed. Service providers that support an eCRM system are concerned with issues such as: extensibility of service model to provide custom (tailored) services to the enterprise. In addition, when an enterprise makes use of an Internet service provider to reach a customer, service level agreements must be set up between the ISP and the enterprise to ensure QoS.

4.0 Analysis of eCRM metrics

We can view the metrics from the customer-centric, business centric and technology-centric viewpoints as belonging to one of the following categories: mutually exhaustive, mutually exclusive and non-overlapping. Mutually exhaustive metrics reinforce each other across stakeholders in the eCRM system, while mutually exclusive metrics are critical for some stakeholders and are non-beneficial or annoying to other stakeholders. Non-overlapping metrics are essential for some stakeholders and do not impose any restrictions on the other stakeholders. Tables 2, 3 and 4 list the mutually exhaustive, mutually exclusive and non-overlapping metrics for the three stakeholders of an eCRM system. An effective customer interaction eCRM system design should be aimed at maximizing the mutually exhaustive metrics, minimizing the effects of mutually exclusive metrics and optimizing the overlapping metrics within cost objectives.

5.0 Conclusion

This paper analysed the requirements for customer interaction in an eCRM system and has proposed a set of metrics from the customer, business and technology perspective. It is seen that eCRM customer interaction metrics from these three stakeholder viewpoints can be categorized as mutually exhaustive, mutually exclusive and non-overlapping requirements. An eCRM system design should aim at maximizing the mutually exhaustive requirements, minimizing the effects of mutually exclusive requirements and optimizing the non-overlapping requirement within cost objectives to enable effective electronic customer interaction. Part II of this paper reviews the features and the services offered by some of the protocols as proposed by the Internet Engineering Task Force (IETF) with respect to their effectiveness in enabling customer interaction, and derives an IETF based protocol suite that may be used in an eCRM system [8].

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7.0 List of abbreviations used in the paper

eCRM	- electronic Customer Relationship Management
IETF	- Internet Engineering Task Force
ISP	- Internet Service Provider
ITU	- International Telecommunication Union
PSTN	- Public Switched Telephone Network
QoS	- Quality of Service
SIP	- Session Initiation Protocol
TINA	- Telecommunications Information Networking Architecture Consortium

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L'Institut en génie de l'énergie électrique: un modèle unique de collaboration université-industrie pour la formation de la relève

by Géza Joós, directeur général de l'Institut
et Guy Scott, Trans-Énergie, Montréal, QC

Abstract

As a result of evolving technological and structural factors, industry will need an increasing number of electrical power engineers. The creation of the Institute is the response of one of the largest Canadian utilities to the need for training the new breed of power engineers it plans to recruit in the next 10 years. The article describes the mandate and structure of the Institute, the cooperation and involvement of universities and industry, and the proposed training.

Sommaire

L'industrie aura besoin d'un nombre croissant d'ingénieurs spécialisés en génie de l'énergie électrique, un besoin lié à de nouveaux facteurs technologiques et structurels. La création de l'Institut est la réponse d'une des plus grandes entreprises d'électricité canadienne à la formation de la nouvelle génération d'ingénieurs qu'elle compte recruter durant les 10 prochaines années. L'article décrit le mandat et la structure de l'Institut, la collaboration et l'implication des universités et de l'industrie, et la formation proposée.

1.0 Introduction

Si depuis plus de vingt ans, le nombre d'étudiants se spécialisant en électrotechnique se maintenait à un niveau faible dans la plupart des universités du Québec, tout autant que dans le reste de l'Amérique du Nord, ce nombre a diminué dernièrement suite à l'engouement pour les nouvelles technologies de l'information. En conséquence, la plupart des universités ont réduit l'importance de leurs programmes en énergie électrique. Cette attrition des programmes correspondait aussi à l'attitude de l'industrie ces dernières années: réduction des effectifs, absence presque totale de recrutement de jeunes ingénieurs, réduction du soutien à l'enseignement et à la recherche. Pourtant, l'industrie de l'énergie électrique vit de changements majeurs: sa restructuration, qui requiert de nouvelles approches technologiques et commerciales, les nouvelles technologies et les nouvelles contraintes d'opération, et les départs massifs à la retraite s'échelonnant sur les 10 prochaines années. Cette situation préoccupe aussi les principales organisations scientifiques impliquées dans l'industrie électrique, soit le Conseil International des Grands Réseaux Electriques (CIGRE), qui a mis sur pied un groupe de travail chargé d'examiner la question [1], et l'IEEE [2]. La création de l'Institut et son financement par Hydro-Québec sont une réponse directe et concrète aux problèmes de l'industrie et permettront de relancer la formation en énergie électrique à travers tout le réseau universitaire québécois. Parmi les actions envisagées, on compte sur une nouvelle formation en énergie axée sur les besoins de l'industrie, comprenant de nouveaux cours et laboratoires, des projets industriels, des stages en industrie et sur une implication concertée de l'industrie dans le programme de formation.

2.0 La situation dans les universités et le marché de l'emploi

Pendant des années, la plupart des universités du Québec ont offert des orientations en énergie électrique, discipline traditionnellement connue sous le nom d'électrotechnique, à un nombre généralement faible mais stable d'étudiants. Le domaine a longtemps été perçu comme ayant atteint sa maturité et offrant peu de défis technologiques. Les possibilités de carrière restaient limitées et peu attrayantes du fait de l'absence de recrutement important dans les grandes entreprises. Les coupures budgétaires dans les universités, au milieu des années 1990, ont forcé beaucoup d'institutions à réduire le nombre de cours offerts dans cette discipline, voire à l'abandonner complètement. De plus, l'attrait marqué des étudiants pour les domaines liés aux technologies de l'information, à savoir les télécommunications et l'informatique, a encore contribué à la réduction du nombre de candidats à la formation en énergie électrique. En conséquence, durant les deux dernières décennies, peu de ressources matérielles, en particulier au niveau des laboratoires, ont été consacrées par la plupart des universités à ce domaine, et peu de postes de professeur ont été créés. Dans certaines universités, on a même assisté à des suppressions de postes. Dans le contexte actuel, la formation en électrotechnique est en général peu justifiable financièrement pour la plupart des universités.

Pourtant, depuis deux ans, la situation au niveau de l'offre d'emploi connaît un revirement. Les entreprises produisant de l'électricité, comme Hydro-Québec, ou celles fabriquant du matériel de production et de conversion d'énergie, de même que celles offrant des services dans ce domaine, voient leur personnel et leur expertise diminuer à cause des départs à la retraite. Par ailleurs, on prévoit des investissements importants dans de nouveaux équipements de production d'électricité. À cela s'ajoutent de nouvelles structures et méthodes de fonctionnement des systèmes de production d'électricité, liées entre autres à la déréglementation des marchés. Finalement, l'électronique de puissance a pris un essor considérable, en particulier à cause des besoins des nouvelles technologies de l'information et de la commande industrielle. Les universités ont donc noté récemment une augmentation significative des offres d'emploi, qu'elles ne sont pas en mesure de combler faute de candidats. De plus, face à l'évolution de la nature des emplois en génie de l'énergie électrique, il s'avère nécessaire de repenser le contenu et la nature de la formation.

3.0 La nécessité d'une action concertée

Compte tenu des mécanismes de financement des universités et du peu d'attrait de la discipline auprès des étudiants, la relance des activités d'enseignement et de formation exigeait une action concertée. Certaines universités, dont l'Université Concordia et l'École Polytechnique, conscientes des difficultés auxquelles elles ont eu à faire face pour maintenir leurs activités en génie de l'énergie électrique, se sont donc adressées à Hydro-Québec, à l'automne 2000 pour lui proposer la création d'un institut dans ce domaine. Quatre autres universités de la Province de Québec, dont les universités McGill, Laval, de Sherbrooke, et l'École de technologie supérieure se sont jointes aux discussions avec Hydro-Québec. Ces discussions ont abouti, en automne 2001, à création de l'Institut en génie de l'énergie électrique (IGEE). L'objectif premier de cet Institut est de relancer, grâce au financement d'Hydro-Québec, la formation en génie de l'énergie électrique, en particulier au premier cycle, soit celui du diplôme d'ingénieur.

4.0 L'Institut, une solution globale à la formation

Compte tenu des besoins limités d'Hydro-Québec, soit environ 25 étudiants par an, sur les 10 à 15 prochaines années, auxquels viendraient s'ajouter environ 15 étudiants recrutés par les autres entreprises de l'industrie électrique, il a été décidé de regrouper les ressources et d'offrir un programme unique, répondant aux attentes générales de l'industrie. Étant donné que les compétences requises d'un ingénieur en génie de l'énergie électrique doivent rester de nature fondamentale, le programme de spécialisation proposé ne couvrira que la dernière année du diplôme d'ingénieur, qui en compte normalement quatre. De plus, pour cette dernière année, on cherchera à regrouper, dans la mesure du possible, les étudiants à un seul endroit, à savoir les locaux de l'Institut. On utilisera les ressources professorales des universités participantes, ainsi que, dans la mesure du possible, leurs laboratoires spécialisés. Le financement d'Hydro-Québec servira à la préparation du nouveau programme et au développement de cours et de laboratoires spécifiques. Des fonds seront consacrés à la mise sur pied d'un programme de formation continue et au développement de cours aux cycles supérieurs. Enfin, l'Institut fournira un soutien au regroupement des chercheurs et au développement d'infrastructures et de laboratoires inter-universitaires.

L'Institut, de par sa structure et son indépendance vis à vis des universités, maintiendra une grande souplesse dans son programme de formation et pourra répondre rapidement aux besoins évolutifs des industries électriques. Ayant son siège social dans des locaux mis a sa disposition par l'École Polytechnique de Montréal, l'Institut disposera de salles de cours, de laboratoires d'enseignement et de recherche, et de locaux administratifs. Toutefois, l'Institut respectera, de par sa nature et son mode de fonctionnement, les modes de fonctionnement des universités.

5.0 La formation en génie de l'énergie électrique

L'Institut a pour mission de former des spécialistes dans les principaux aspects du génie de l'énergie électrique, incluant la génération, le transport, la distribution et la conversion d'énergie. L'ingénieur devant avoir une solide formation de base en génie et en génie électrique, celle-ci sera laissée aux universités et l'Institut n'encadrera que la spécialisation. Cette formation spécialisée servira les besoins non seulement d'Hydro-Québec, mais aussi des fournisseurs de matériel et de services. Elle couvrira les questions touchant la planification et l'expansion des réseaux électriques, la production d'une énergie électrique de qualité et l'intégration des nouvelles technologies d'information et de commande. L'électronique de puissance, de plus en plus employée, sera aussi enseignée, compte tenu des besoins industriels importants. De plus, afin de permettre aux étudiants d'accéder à un marché du travail plus vaste, tant au niveau local qu'international, une partie des cours du programme seront offerts en langue anglaise.

Pour l'année académique 2002-2003, le programme encadré par l'Institut et adopté par toutes les universités participantes comprend six cours obligatoires, formant la concentration en génie de l'énergie électrique : électronique de puissance, réseaux électriques, systèmes électromécaniques, électricité industrielle, appareillage et commande industrielle. L'Institut prévoit aussi mettre sur pied des cours optionnels sur les sujets suivants : matériaux de l'électrotechnique, réglementation, normes et environnement, comportement des réseaux électriques et protection des réseaux électriques. Tous les cours sont assortis de laboratoires. L'industrie participe à la définition des contenus et dans certains cas fournit l'expertise technique. Compte tenu de la participation d'universités à l'extérieur de la région de Montréal, on envisage la possibilité de développer des cours de formation à distance.

Avec ce nouveau programme, on espère attirer en nombre suffisant les meilleurs d'étudiants. Une publicité appropriée et des mesures incitatives devraient assurer une plus grande visibilité et un plus grand attrait pour la discipline : bourses, stages, offres d'emploi, entre autres. De plus, avec le soutien d'Hydro-Québec et de l'industrie, des campagnes de recrutement seront menées pour sensibiliser les étudiants aux nombreuses possibilités de carrières offertes dans le domaine de l'énergie électrique, et pour améliorer l'image de la profession.

6.0 Le partenariat universitaire

Le programme de formation développé par l'Institut sera mis à la disposition des universités participantes, qui participeront au recrutement des étudiants. Même si ceux-ci suivent les cours de l'Institut, ils resteront inscrits dans leur université d'attache et obtiendront leur diplôme de cette université. Grâce à ses ressources et à son financement, l'Institut permettra d'offrir un programme diversifié en énergie électrique. Le corps professoral proviendra essentiellement des ressources existantes dans les universités et, dans la limite de ses moyens. L'Institut cherchera également à financer de nouveaux postes de professeur, assurant ainsi la relève du corps professoral. Enfin, les laboratoires spécialisés de ces institutions seront aussi mis à contribution.

7.0 La contribution des industries

Hydro-Québec et les industries participantes seront invités à participer à la définition des programmes d'étude et à impliquer leur personnel, comme chargés de cours et experts, dans les enseignements. On compte en particulier sur leur expertise dans le développement des aspects pratiques de la formation, à savoir les travaux dirigés et l'apprentissage en laboratoire. L'industrie sera invitée à soutenir la mise en place de ces laboratoires spécialisés. Parallèlement, elle sera invitée à offrir des bourses d'études, à encadrer des projets de fin d'études, à offrir des stages en industrie, et dans la mesure du possible proposer des emplois aux finissants.

8.0 Résumé

Grâce à la mise sur pied de l'Institut et à ses activités en génie de l'énergie électrique, Hydro-Québec et les industries participantes auront à leur disposition une main d'oeuvre qualifiée et en nombre suffisant pour satisfaire leurs besoins à court et à long termes. Le modèle proposé pour l'implication de l'industrie dans la formation offre une grande flexibilité : il permettra à l'Institut d'adapter facilement ses programmes et de s'impliquer, non seulement dans la formation de la relève, mais aussi dans la formation continue et dans la formation à distance, et ce tant au niveau du diplôme d'ingénieur et qu'au niveau des études supérieures.

9.0 Remerciements

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Guy Scott a obtenu un B. Sc. A. et une M. Ing. en génie électrique de l'École Polytechnique (Université de Montréal) en 1975 et 1980 respectivement. Depuis 1975, il travaille en planification à Hydro-Québec. Il est présentement Chef Études de réseau et Critères de performance à la Direction Planification des Actifs et Affaires réglementaires de Hydro-Québec - TransÉnergie. Il est membre de l'IEEE et de l'Ordre des Ingénieurs du Québec.

Hommage à Jean-Jacques Archambault

Le 23 décembre dernier, le Québec perdait l'un de ses plus brillants inventeurs. Il s'agit de monsieur Jean-Jacques Archambault, ingénieur retraité d'Hydro-Québec et inventeur de la ligne à 735 kV. Au début des années 60, cette invention constituait une première mondiale qui valut à l'entreprise la reconnaissance de tous les spécialistes du domaine de l'électricité. Au début de l'année 2001, l'Ordre des technologues professionnels du Québec nommait l'introduction de la technologie de transport à 735 kV la technologie québécoise du XXe siècle.

Afin de manifester concrètement son engagement à l'égard des étudiants du programme de l'Institut, Hydro-Québec vient de décerner en mars 2002 sept bourses Jean-Jacques-Archambault d'un montant de 5 000 $ chacune aux diplômés de la promotion 2001-2002. Les bourses ont été nommées en mémoire de cet ingénieur passionné de recherche qui devrait leur servir de modèle. L'entreprise espère pouvoir attribuer 15 bourses par année aux étudiants des promotions à venir.

Wind Energy Conversion Systems

by *Liuchen Chang*
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Abstract

Wind power capacity has experienced tremendous growth in the past decade, thanks to wind power's environmental benefits, technological advance, and government incentives. This paper presents the recent developments in wind energy conversion systems, and their social and environmental benefits. The paper provides a review of the interconnection issues of distributed resources including wind power with electric power systems, and reports the developments of interconnection standards in Canada and IEEE. The paper also describes the recent R&D programs in wind energy conversion systems.

Sommaire

Le potentiel de l'énergie éolienne a connu une forte croissance lors de la dernière décennie, cela est du aux avantages écologique de cette énergie, aux percées technologiques dans le domaine et aux aides gouvernementales incitatives. Cet article présente les récents développements dans les systèmes de conversion d'énergie basés sur l'énergie éolienne et leurs avantages sociaux et environnementaux. Cet article présente aussi une revue des problèmes liés à l'interconnexion de ressources distribuées comprenant l'énergie éolienne et les systèmes électriques et rapporte les développements de standards d'interconnexion au Canada et au sein de l'IEEE. Cet article décrit enfin les récents programmes de recherche et développement dans les systèmes de conversion d'énergie.

1.0 Introduction

Differential heating of the earth's surface by the sun causes the movement of large air masses on the surface of the earth, i.e., the wind. Wind energy conversion systems convert the kinetic energy of the wind into electricity or other forms of energy. Wind power generation has experienced a tremendous growth in the past decade, and has been recognized as an environmentally friendly and economically competitive means of electric power generation.

More and more countries are ratifying the 1997 Kyoto Protocol, and wind power has become one of the most effective ways to reach its goals. The Kyoto Protocol sets targets for participating countries to reduce greenhouse gas emissions to at least 5% below the 1990 level in the commitment period of 2008 to 2012. According to the U.S. Energy Information Administration, world electricity consumption will increase from 12,833 TWh in 1999 to 22,230 TWh in 2020, mainly driven by developing countries, where two billion people are still without access to electricity [1]. The fuel mix for the world's electricity generation in 1999, as presented in Figure 1, indicates that fossil fuels accounted for 62% while renewables including hydropower, wind and solar etc. accounted for 20.2% [2].

Based on a life-cycle assessment of these power generation options conducted by Hydro Quebec, the greenhouse gas emissions from the 1999 fuel mix are 510 kilotons of equivalent CO2 per TWh [3], as compared to 9 kilotons of equivalent CO2 per TWh from wind power. A 660 kW wind turbine operating at a 0.35 annual capacity factor can generate about 2 GWh of electricity per year, enough for 250 typical Canadian homes. This single wind turbine can displace 1,000 tonnes of equivalent CO2 emissions based on the 1999 world fuel mix for electricity generation. If this wind turbine were to displace the electricity generated by a coal fired power plant, 1,930 tonnes of equivalent CO2 emissions could be avoided.

In addition to business opportunities as a result of deregulation in the electricity market, wind power generation has great potential to create employment in wind system development, manufacturing, maintenance and operation [4]. Table 1 shows the direct job creation by wind power as compared to other power generation technologies [5].

2.0 Recent Development in Wind Industry

2.1 Installed Capacity

Worldwide development of wind energy expanded rapidly starting in the early 1990s. As shown in Figure 2, the average annual growth rate from 1994 to 2001 of the world installed capacity of wind power is 31% [6], making the wind industry one of the fastest growing. Unlike the last surge in wind power development during 1970s and early 1980s which was due mainly to the oil embargo of the OPEC countries, the current wave of wind energy development is driven by many forces that make it favorable. These include its tremendous environmental, social and economic benefits, its technological maturity, the deregulation of electricity markets throughout the world, public support and government incentives. In Denmark wind power accounted for 18% of electricity consumption in 2001, and this share will be increased to 50% by 2030. Canada has a total of 198 MW of installed wind power capacity as of 2001, with additional wind plants planned in Ontario, PEI and Alberta. Canada has tremendous wind resources from coast to coast. According to the Canadian Wind Energy Association (CanWEA), if the right government policies are implemented, wind energy can contribute 5% of Canada's electricity supply by 2010. CanWEA has released Wind Vision for Canada, recommendations for achieving 10,000 MW of installed wind power capacity by 2010.

Figure 1: Fuel mix for world electricity generation in 1999.

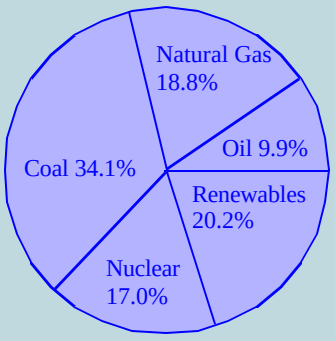

Table 1: Direct Job Creation

Technology	Jobs/TWh/yr
Nuclear	100
Geothermal	112
Coal 1	16
Solar Thermal	248
Wind	542

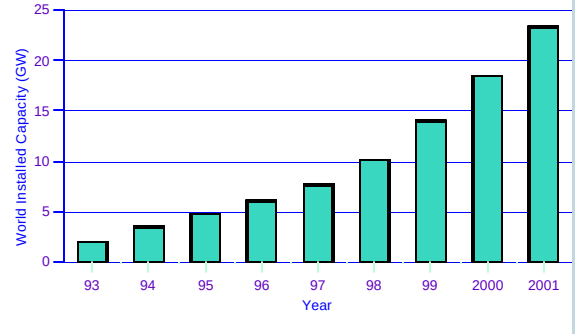

Figure 2: World installed capacity of wind power.

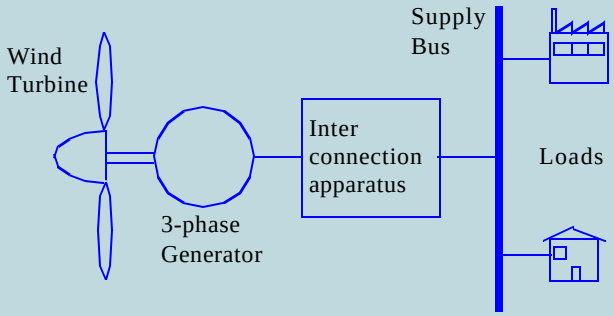

Figure 3: Structure of a typical wind energy system.

2.2 Technological Advance

Thanks to extensive R&D efforts during the past 30 years, wind energy conversion has become a reliable and competitive means for electric power generation. The life span of modern wind turbines is now 20-25 years, which is comparable to many other conventional power generation technologies. The average availability of commercial wind power plants is now around 98% [6]. The cost of wind power has continued to decline through technological development, increased production level, and the use of larger turbines. The cost of energy from wind power has fallen from around 35 ¢US/kWh in 1980 to 4-6 ¢US/kWh today [6][7]. The average capacity of new wind turbines deployed grew to 805 kW and the average installed capacity cost fell to $1000 US/kW in 2000. Table 2 presents a recent cost analysis for various wind power plants, if installed in Canada in 2001 [8]. In this table, "Large Wind Plant" is targeted at utility grade power generation; "One Small Turbine" is used for distributed generation for residential loads; and "Remote Community" refers to wind-diesel systems in remote communities.

2.3 Incentive Programs

The main market stimulation instruments for wind power development are a combination of capital subsidy and payment of premium prices for energy production. In a deregulated electricity market, many wind power generators can sell their electrical energy at a "green power premium." In Canada, the Federal Income Tax Act provides an accelerated rate of write-off for wind capital costs, allows the first exploratory wind turbine of a wind plant to be fully deducted in the year of its installation, and allows the use of flow-through share financing. In December 2001, the Federal Government implemented a wind power production incentive. The incentive includes a payment of 1.2 cents per kWh of production, gradually declining to 0.8 cents per kWh, and is available for the first 10 years of production.

Table 2: Costs of Various Wind Power Plants

Cost in Cdn $	Large Wind Plant	One Small Turbine	Remote Community
Plant Capacity (kW)	75,000	10	325
Turbine Size (kW)	750	10	65
Capital Cost ($/kW)	$1,400	$3,500	$3,000
Financing Rate (%)	7.5%	10%	8.5%
Capacity Factor (%)	35%	23%	25%
Energy Cost($/kWh)	$0.058	$0.237	$0.195

3.0 Structure of Wind Energy Conversion Systems

The major components of a typical wind energy conversion system include a wind turbine, generator, interconnection apparatus and control systems, as shown in Figure 3. Wind turbines can be classified into the vertical axis type and the horizontal axis type. Most modern wind turbines use a horizontal axis configuration with two or three blades, operating either down-wind or up-wind. The major components in the nacelle of a typical wind turbine are illustrated in Figure 4. A wind turbine can be designed for a constant speed or variable speed operation. Variable speed wind turbines can produce 8% to 15% more energy output as compared to their constant speed counterparts, however, they necessitate power electronic converters to provide a fixed frequency and fixed voltage power to their loads. Most turbine manufacturers have opted for reduction gears between the low speed turbine rotor and the high speed three-phase generators. Direct drive configuration, where a generator is coupled to the rotor of a wind turbine directly, offers high reliability, low maintenance, and possibly low cost for certain turbines. Several manufacturers have opted for the direct drive configuration in the recent turbine designs.

At the present time and in the near future, generators for wind turbines will be synchronous generators, permanent magnet synchronous generators, and induction generators, including the squirrel cage type and wound rotor type. For small to medium power wind turbines, permanent magnet generators and squirrel cage induction generators are often used because of their reliability and cost advantages. Induction generators, permanent magnet synchronous generators and wound field synchronous generators are currently used in various high power wind turbines.

Interconnection apparatuses are devices to achieve power control, soft start and interconnection functions. Very often, power electronic converters are used as such devices. Most modern turbine inverters are forced commutated PWM inverters to provide a fixed voltage and fixed frequency output with a high power quality. Both voltage source voltage controlled inverters and voltage source current controlled inverters have been applied in wind turbines. For certain high power wind turbines, effective power control can be achieved with double PWM (pulse width modulation) converters which provide a bi-directional power flow between the turbine generator and the utility grid.

4.0 Interconnection with Electric Power Systems

Thirty six states in US have adopted, and several Canadian provinces are considering adopting net metering programs, under which a utility customer can install a small on-site renewable power generator and sell electricity to the utility at the same rate at which he purchases it from the utility. Net metering programs have substantially improved the economy of small distributed resources (DR), including wind power. Although standards exist for large power plants connected to electric power systems, they fail to address special requirements for distributed resources. To provide guidelines for all stakeholders including utilities, independent power producers, users and equipment manufacturers, efforts are being made, both in Canada and internationally, to develop interconnection standards. Supported by Natural Resources Canada and Industry Canada, Electro-Federation Canada is developing Canadian guidelines for connecting small distributed resources to grids [9]. The

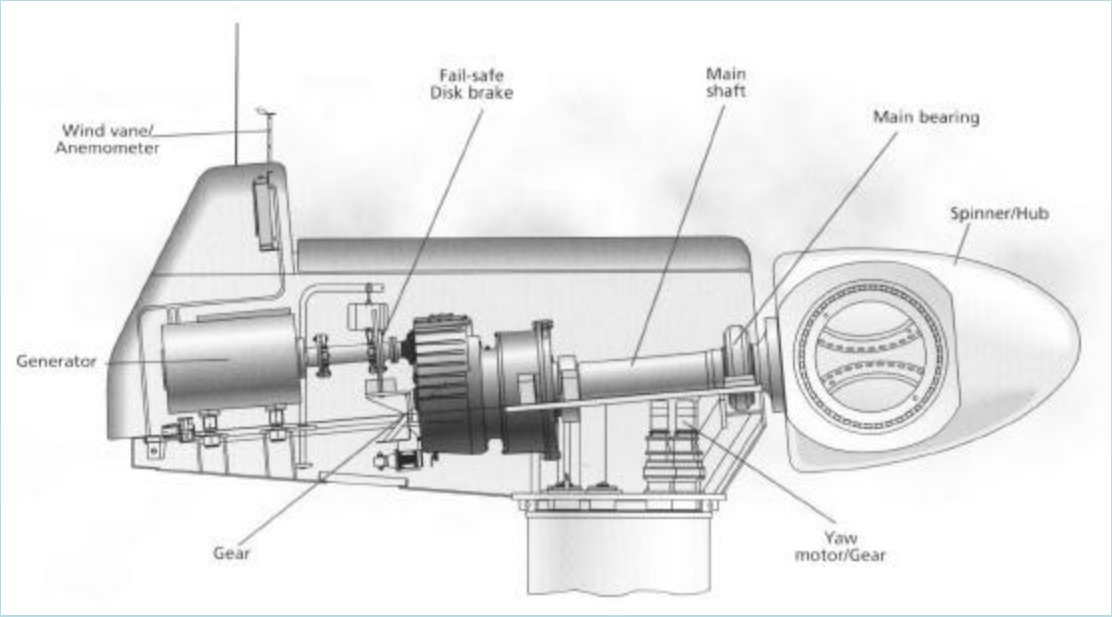

Figure 4: Major components inside the nacelle of a turbine.

guidelines will mainly address the interconnection issues of inverter-based small power generators such as photovoltaics, wind, fuel cells and microturbines. IEEE Standards Coordinating Committee 21 on Fuels, Photovoltaics, Dispersed Generation, and Energy Storage had formed working groups to develop IEEE P1547, the Draft Standard for Inerconnecting Distributed Resources with Electric Power Systems, and P1589, the Draft Standard for Conformance Tests Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems (EPS).

Distributed resources connected with electric power systems are presented in Figure 5 as typical configurations. The major interconnection requirements for distributed resources can be summarized in the following three categories: general specifications, safety and protection, and power quality.

4.1 General Requirements

Voltage Regulation: A DR shall not cause the voltage at the Point of Common Coupling (PCC, see Figure 5) to go outside of Range A specified by Standard ANSI C84.1(or CSA CAN3-C235-83) [10]. For a 120/240V system, this specifies a maximum voltage of 126/252V and a minimum voltage of 114/226V.

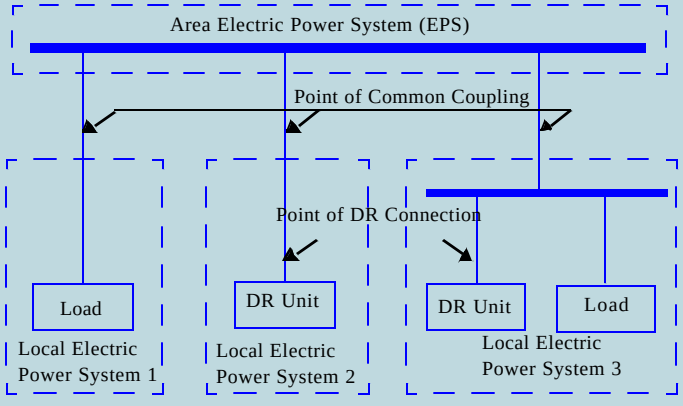

Figure 5: Distributed resources connected to a power system.

Synchronization: When synchronizing, a DR shall not cause more than +/-5% of voltage fluctuation at the PCC.

Monitoring: A DR of 250 kW or larger shall have provisions for monitoring connection status and real and reactive power output at the DR connection.

Isolation Device: A readily accessible, lockable, visible-break isolation device shall be located between the DR and the EPS.

4.2 Safety and Protection Requirements

Voltage Disturbances: At abnormal voltages, a DR shall cease to energize the EPS within the specified clearing time.

Frequency Disturbances: A DR shall cease to energize the EPS if the frequency is outside the range 59.3 - 60.5 Hz.

Loss of Synchronism: A DR of 250 kW or larger shall have loss of synchronism protection function.

Reconnection: A DR may reconnect to the power system 5 min. after the EPS voltage and frequency return to normal.

Unintentional Islanding: A DR shall cease to energize the EPS within 2 sec. of the formation of an island.

4.3 Power Quality Requirements

Harmonics: The total demand distortion of a DR, which is defined as the total rms harmonic current divided by the maximum demand load current, shall be less than 5%. Each individual harmonic shall be less than the specified level.

DC Current Injection: A DR shall have a dc current injection of less than 0.5% of its rated output current.

Flicker: A DR shall not create objectionable flicker for other customers on the area EPS.

5.0 Test Facilities for Wind Energy Conversion Systems

To meet the increasing demands for wind power applications, tremendous R&D effort is needed to develop safe, reliable and cost effective technologies for wind energy conversion. Supported by the Canadian Foundation of Innovation, Atlantic Wind Test Site Inc., Natural Resources Canada and Université de Moncton, the University of New Brunswick has established a unique R&D and test facility for wind and

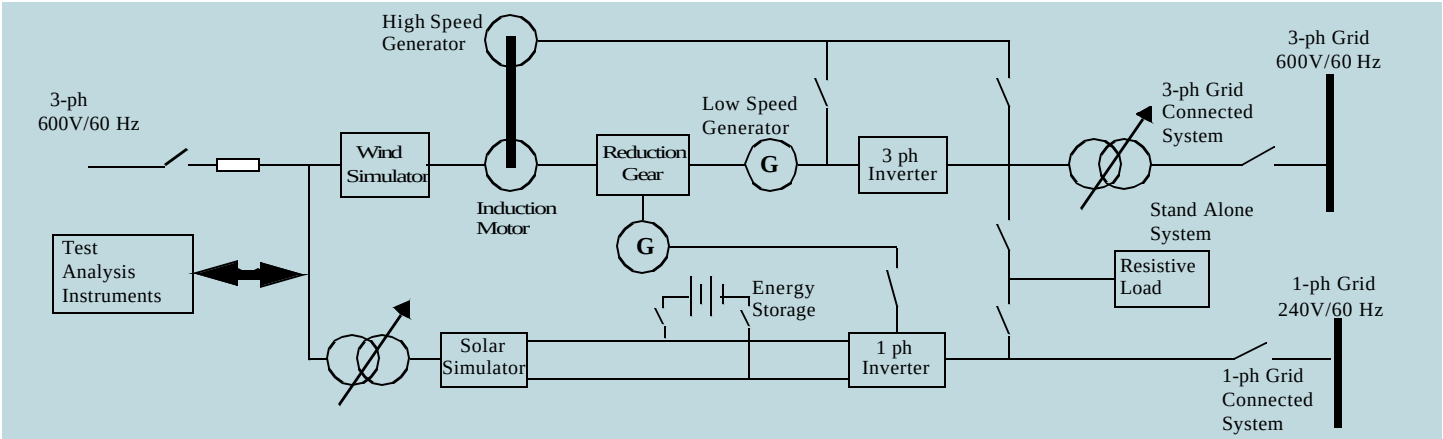

Figure 6: Single Line Diagram for UNB test facility for wind and solar energy conversion systems.

solar energy conversion systems. It is located close to the 5 MW wind plant at the Atlantic Wind Test Site in PEI. As illustrated in Figure 6, this facility includes wind and solar energy conversion components of various structures, such as high speed generators (fixed or variable speed, up to100 kW), direct drive variable speed generators (wound field and permanent magnet synchronous generators, up to 50 kW), a three-phase inverter (100 kW), single-phase inverters (grid-connected or autonomous, up to 25 kW), and storage batteries.

In particular, the wind turbine simulator provides researchers with a controlled test environment for wind turbine generators, inverters and system operations, resulting in improved research productivity. The facility also provides an infrastructure for the development of advanced control methodologies to improve aspects of system performance such as maximum power extraction from wind or solar sources. The wind turbine simulator emulates the output characteristics of a wind turbine at various wind speeds using an adjustable speed induction drive system [11], as shown in Figure 7. For the turbine generator and power electronic converters, the induction motor drive behaves the same as a variable speed wind turbine. The wind simulator, as a part of the test facility for wind and solar energy conversion systems is shown in Figure 8 along with various generators.

Currently, the researchers at the University of New Brunswick are focusing on the development of innovative power electronic converters and advanced control strategies for variable speed wind turbine systems. Two of the several development platforms include the single-phase 10kW/240V grid-connected IGBT inverter used on a Bergey Excel 10 kW wind turbine in Charlottetown, PEI, and the three-phase 100kW/380V grid-connected IGBT inverter used on a Lagawey LW18 80kW wind turbine in North Cape, PEI. The 10 kW system was developed for residential power generation (Figure 9), and the 100 kW system was developed for wind-diesel applications in remote communities (Figure 10). Figure 11 shows another view of the site. The R&D work has expanded to include distributed generation packages powered by micro-hydro units and microturbines, in addition to wind turbines.

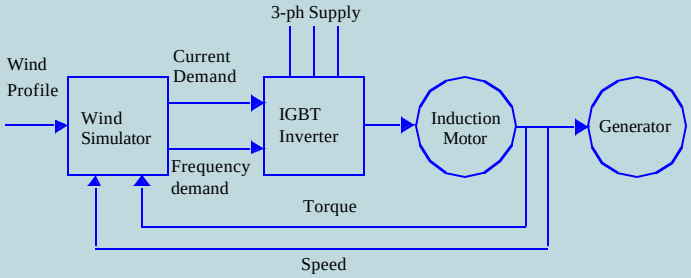

Figure 7: Wind turbine simulator.

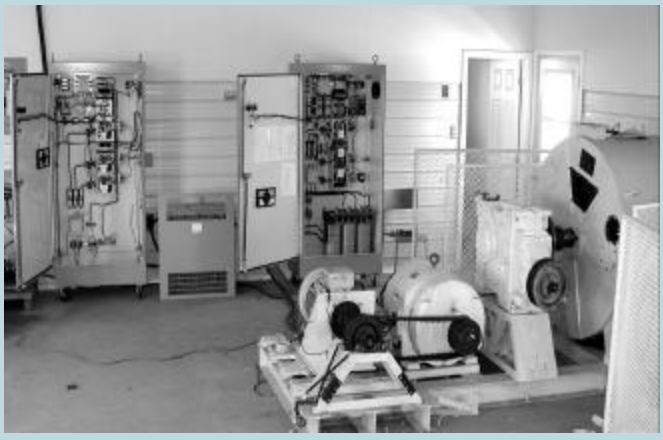

Figure 8: Wind turbine simulator.

Figure 9: Bergey Excel 10 kW wind turbine for inverter research and development.

Figure 10: Lagawey LW18 80 kW wind turbine for inverter research and development.

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About the author

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He is a professor of Electrical and Computer Engineering and NSERC Chair in Environmental Design Engineering at the Department of Elect. & Comp. Eng., University of New Brunswick.

His principal research interests and experience include distributed power generation, renewable energy conversion, analysis and design of electrical machines, variable-speed drives, power electronics, and electric vehicle traction systems. LChang@unb.ca.

Figure 11: A view of the Windmill park in PEI. The photograph shows the 5.28 MW North Cape Wind Plant and wind test facilities of Atlantic Wind Test Site Inc. (AWTS), located at North Cape, the northernmost tip of Prince Edward Island.

How To Brighten Your Style - Part 1

by Cheryl and Peter Reimold,
PERC Communications, Scarsdale, NY

SUMMARY SENTENCE:

Strong words are rooted in necessity, immediacy, honesty, and sound appeal.

1.0 Word choice

One of the questions we are most frequently asked is, "How can I simplify my style without making it boring or grade-school level writing?" In this series of columns, we will offer several suggestions to brighten your style, beginning with the atom of language: the word.

2.0 What Makes a Good Word?

Here are some features of a strong word:

Necessity: It adds new, useful information as concisely as possible.

(Shall I compare thee to a summer's day? vs. Would it be advantageous and appropriate to attempt a comparison between the object of my attentions and a salubrious estival quotidian period?)

Immediacy: It instantly transmits the picture, action, or idea in the writer's mind. (To be or not to be - that is the question. vs. The problem of pursuing continued if somewhat undesirable existence or, by contrast, endorsing the imminent possibility of concluding that existence remains the issue to be considered.)

Honesty: It doesn't hide meanings or try to sound impressive. (Help! vs. Immediate succor would be inestimably appreciated.)

Sound appeal: It is easy and pleasant to say, and it forms a rhythm with other words around it. (A thing of beauty is a joy forever. vs. An object of considerable aesthetic qualities may be said to elicit satisfaction for an immeasurable period.)

This article is the first in a series of "tips and techniques" to help you develop an effective communication style. Effective communication is essential for success in today's highly competitive, global, team- based business environment. Engineers as well as others often assume - wrongly! -- that the information speaks for itself and that technical jargon is universally understood. Taking time to organize your thoughts before communicating has value in engineering communication by making your message concise, complete, persuasive, interesting, and understandable to all. We hope that this series will be of value to you professionally and personally. We value your feedback.

3.0 The Criteria Applied

Using these criteria, we can quickly change some unattractive, hard-to-read statements into pieces of good writing. For instance, take this original statement:

> *The data presented in Table 2 clearly show the non dependence of the optimum sulfidity on the chemical concentration of the liquor.*

Let's see if any words here violate the principles of necessity, immediacy, honesty, or sound appeal.

Necessity. Is every word here necessary? Does it add new, useful information? Two jump out for dismissal: presented and clearly. They add nothing valuable. Result: The data in Table 2 show the non dependence of the optimum sulfidity on the chemical concentration of the liquor.

Immediacy. Does each word present an immediate picture, action, or idea, or do we have to translate it into other words to get the message? Non dependence fails that test. You can't see a non dependence. Yet the previous words - "The data in Table 2 show" - point toward an event or action; the data must show something happening. To get the message, we have to translate the negative, abstract word non dependence into a positive statement of an action. What do the data show? The data in Table 2 show that optimum sulfidity does not depend on the chemical concentration of the liquor.

Now we get the picture immediately. The sentence works; we can move on.

Let's look at another statement:

> *To mitigate these incipient problems, a misguided effort by the production improvement team resulted in certain precipitate remedial actions.*

Whew! This sentence has an almost total lack of immediacy, honesty, and sound appeal. We do not get the message immediately. To approach it, we have to remove or translate at least four words -- mitigate, incipient, precipitate, and remedial -- or translate them into expressions with clear meanings. These words do not feel honest. They are long, rarely used words that suggest a pompous screen behind which the writer is trying to hide his message. Finally, they sound terrible; we can hardly say them.

Once we refuse to use these words, the sentence changes. It turns into something like this:

> *In its efforts to solve these problems, the production improvement team took some rash actions.*

Try applying these four principles to the words you write. Are all the words in your document necessary? Do they immediately transmit pictures or events? Are they honest and unpretentious? Do they sound good when you say them aloud? If so, you have made a good choice of words. Next time we'll see how to put them together.

Cheryl and Peter Reimold (telephone 1+ 914-725-1024, e-mail perccom@aol.com) have taught communication skills to engineers, scientists, and businesspeople for 18 years. Visit their new educational web site at www.allaboutcommunication.com.

IEEE Member in the News

Dr. O.P. Malik, Professor Emeritus, Department of Electrical and Computer Engineering, University of Calgary, has been awarded the APEGGA Alberta Ingenuity Fund Research Excellence Award for the year 2002.

"The award recognizes professionals in academia or industry who have conducted innovative research in engineering, geology or geophysics, and that research has been successfully applied to improve our economic and social well being."

"The Association of Professional Engineers, Geologists and Geophysicists of Alberta (APEGGA) bestows eleven prestigious Summit Awards which recognize leadership and excellence in the practice of engineering, geology and geophysics, and the contribution of APEGGA professionals to the economy and to their communities."

Life Members (LM) Committee

Our First Baby Step

Time flies and already we are well into 2002. With the new year comes good news. Ron Potts, Chair of the IEEE-Canada Life Members (LM) Committee, reports that the LM Chapter formation in the IEEE Central Canada Council is well underway. Visits by him to the IEEE Sections in that Council have resulted in the identification of LM representatives at the local level.

With the establishment of a new Life Member Chapter for Central Canada we can look forward to a greater use of Life Members as a resource for Section activities. For those of you who are not aware of IEEE-Canada's structure I should point out that we have three regional Councils - Western, Central and Eastern. Central Council has by far the largest Section membership and is geographically more concentrated. Thus it was the obvious choice for our first "baby step" in LM Chapter formation.

Chair Potts visited with each of the six Sections in Central Council and was successful in recruiting a Life Member in each to approach and work with the local Section executive. In particular, he outlined areas of participation in which active LMs might be of assistance. These are:

- Undertake a local inventory analysis of LMs, updating contact addresses,
- Host meetings and social events of interest,
- submit newsletter articles to Region and Section newsletters,
- Promote recognition of the history of our technologies within IEEE-Canada,
- Interface with the Engineering Institute of Canada's LMs,
- Promote historical articles in the "**IEEE Canadian Review**", and
- Recommend award nominees to the IEEE Awards and Recognitions Committee.

The Life Members recruited in each of the Central Council Sections are:

Hamilton	- Bert de Kat
Kingston	- V. John
Kitchener-Waterloo	- Thomas East
London	- John Watson
Peterborough	- R. Rehder
Toronto	- Neil Magrath

Their contact addresses can be obtained from IEEE-Canada <c.lowell@ieee.org> or by contacting one of the officers of IEEE-Canada Life Members Committee. I am sure the LM representatives would welcome hearing from all LMs in their respective areas who may be interested in getting involved.

By the time you read this we expect that similar "baby steps" will have been taken in the IEEE-Canada Western and Eastern Councils. Leading that organizational activity in the west is Mohindar Sachdev <m.s.sachdev@dlcwest.com> of the North Saskatchewan Section, and in the east is Wally Read <w.read@ieee.org> of the Newfoundland and Labrador Section. Already two LMs are busy in getting things started - William Moore of the Ottawa Section (East) and Ron Blicq of the Winnipeg Section (West).

Let's hear from more of you in the east and west, so that before we know it we'll graduate from "baby steps" to walking and, yes, even running, with full scale LM activity.

Wally Read, Life Fellow
Newfoundland, Canada.

IEEE Canada

Guidelines for submitting an article to the IEEE Canadian Review

Contact any one of the Associate Editors (address information is available on page 2 of this journal). A short abstract should be sent in and will be reviewed before approvals are given for a full paper submission.

Follow these broad-based guidelines for paper preparation:

- Papers (in English or French) must be on topical subjects of interest to the vast majority of our members across Canada,
- Papers selected for the CR are not the type that would normally be submitted to a Conference or Transactions/Journal type of publication. Any mathematical material must be kept to a minimum,
- Papers are normally about 4 pages long (about 2000 words), but articles can be as short as 1 page or as long as 6 pages,
- Submit text in ascii (or WORD) format, as well as a typeset version in PDF format,
- Graphics and images must only be in two colors (Black and Reflex Blue) or Grayscale; Graphics should be scanned at 300 dpi, in 8 bit Grayscale, and submitted electronically in either tiff, jpeg or gif formats,
- A short Abstract (about 200 words) in English and French is required (we can provide assistance in translation),
- A short biographical note (about 150 words) about the author(s) is also required, together with a passport size photo,
- For samples of previously published articles, see our website at www.ieee.ca, and follow the links to the *IEEE Canadian Review*,
- Items are normally submitted on-line directly to the Editor,
- We particularly encourage articles from small businesses on topics in electrical, electronic, computer or telecommunications related industries etc.
- We encourage academic institutions to present their new programs so that the community is aware of recent program changes,
- Newsworthy items, such as senior appointments in academia and industry, are also welcome.

For further information, contact Vijay Sood, Managing Editor, at:

v.sood@ieee.org

Phone: 450-652-8089

Inauguration de la Chaire CMC Électronique

L'ÉTS au cœur de la recherche appliquée à l'industrie

Université du Québec
École de technologie supérieure

Montréal, le 20 mars 2002 - L'École de technologie supérieure (ÉTS) et CMC Électronique ont inauguré aujourd'hui la Chaire CMC Électronique en télécommunications sans fil. “Ce soutien de CMC Électronique démontre, encore une fois, que nous sommes au cœur de la recherche appliquée à l'industrie”, a commenté le directeur général de l'ÉTS, monsieur Robert L. Papineau.

“L'approche de l'ÉTS se caractérise par ses relations étroites avec notre entreprise et sa disponibilité à travailler à des problématiques qui nous sont propres”, de renchérir monsieur Patrick Champagne, vice-président ingénierie de CMC Électronique. “Cette collaboration en recherche a contribué à l'obtention, pour CMC Électronique, d'un important contrat avec le centre de commandement des communications et de l'électronique (CECOM) de l'armée américaine”, a-t-il ajouté.

Le président-directeur général d'Investissement Québec, monsieur Maurice Prud'homme, a rappelé pour sa part que sa société a déjà accordé en 1998 une aide substantielle de 800 000 $ pour soutenir un projet de recherche et de développement technologique chez CMC Électronique.

Pour la ministre déléguée à l'Industrie et au Commerce, madame Lucie Papineau, “l'inauguration de la Chaire CMC Électronique démontre toute la portée d'une injection judicieuse de fonds publics sur le développement d'une entreprise, le développement de la recherche industrielle et sur la création d'emplois de qualité.”

“Cette chaire est le fruit de l'étroite collaboration, depuis 1997, entre CMC Électronique (autrefois Marconi Canada) et le Laboratoire de communication et d'intégration de la microélectronique (LACIME) de l'ÉTS. Elle permettra de répondre encore plus adéquatement aux besoins de l'industrie dans le développement de systèmes de communications sans fil”, a rappelé le professeur François Gagnon, titulaire de la nouvelle chaire. Cette chaire financera de plus la recherche de plusieurs étudiants de 2e et 3e cycles et permettra le développement de nouvelles technologies qui seront accessibles à CMC Électronique.

Membre du réseau de l'Université du Québec, l'ÉTS est spécialisée dans l'enseignement du génie appliqué et en technologie. Elle vise tout particulièrement le développement de nouvelles technologies et leur transfert en entreprise. Fidèle à sa signature, “le génie pour l'industrie”, elle entretient des liens étroits autant avec les grandes entreprises qu'avec les PME.

CMC Électronique (autrefois Marconi Canada) conçoit et fabrique des produits électroniques de pointe destinés aux marchés de l'aviation, des communications, de la détection à infrarouge, de l'électronique maritime, du positionnement mondial et de l'espace. La Société met au point et fabrique des systèmes électroniques et de communications novateurs depuis 1903. Ses principales installations sont situées à Montréal, Ottawa et Cincinnati. L'apport de ses filiales NovAtel Inc. à Calgary, en Alberta, et de Northstar Technologies, à Acton, au Massachusetts, permet d'étendre les connaissances techniques de la Société.

Dans l'ordre habituel : M. Robert L. Papineau, directeur général de l'École de technologie supérieure; M. Patrick Champagne, vice-président, Ingénierie, CMC Électronique; M. Francois Gagnon, Professeur et Titulaire, Chaire CMC Électronique en télécommunications sans fil, ETS; M. Jean-Michel Comtois, vice-président, Relations gouvernementales, CMC Électronique; et M. Alan Barker, vice-président, Communications militaires, CMC Électronique.

Une subvention de 35 millions de dollars du MÉQ pour l'agrandissement du campus de l'ÉTS

Montréal, le 29 janvier 2002 - Le directeur général de l'École de technologie supérieure (ÉTS), M. Robert L. Papineau, et le ministre de l'Éducation, M. François Legault, ont annoncé aujourd'hui en conférence de presse l'agrandissement du campus de l'École. Pour la réalisation de ce projet, le gouvernement du Québec accorde une subvention de 35 millions de dollars.

En décembre 1996, lors du déménagement de l'École au 1100 de la rue Notre-Dame Ouest, dans l'un des anciens édifices de la brasserie O'Keefe, les prévisions de croissance de la clientèle étudiante faites par le ministère de l'Éducation permettaient de croire que ces locaux pourraient accueillir les étudiants de l'École pour les 15 prochaines années. Toutefois, depuis quelques années, les hausses répétées de la clientèle étudiante ont fait en sorte que l'École a dû réaménager tous les espaces disponibles afin d'augmenter le nombre de ses salles de classe et de laboratoire. L'enseignement coopératif faisant alterner les sessions d'études et de stage, le taux de placement des finissants de l'ÉTS de plus de 95 % et l'ajout d'un programme de baccalauréat en génie logiciel ont largement contribué à la hausse des inscriptions. Rappelons que l'École a connu l'automne dernier une hausse record de 28 % de ses étudiants nouvellement inscrits au baccalauréat. Ainsi, à peine cinq ans plus tard, les locaux actuels sont maintenant utilisés bien au-delà de leur pleine capacité.

D'une superficie totale de 18 650 m2 bruts, le projet d'agrandissement permettra d'accueillir, en équivalence temps complet, près de 1 000 étudiants supplémentaires, ce qui portera à près de 3 500 le nombre des étudiants de l'École. Ce nouvel édifice abritera principalement des salles de cours et de laboratoire ainsi que des bureaux administratifs, un gymnase, une salle de conditionnement physique et une garderie. Le coût total du projet est de 45 millions de dollars.

Fondée en 1974, l'École de technologie supérieure (ÉTS) fait partie du réseau de l'Université du Québec. Spécialisée en ingénierie d'application et en technologie, elle axe ses activités sur l'enseignement coopératif et vise tout particulièrement le développement de nouvelles technologies et leur transfert en entreprise. Grâce à un partenariat unique avec les grandes entreprises et de nombreuses PME, l'École a tissé au fil des ans un solide réseau de liens avec le milieu des affaires et de l'industrie, se hissant ainsi au rang des grandes écoles et facultés de génie du Québec et du Canada.

Projet d'agrandissement de l'École de technologie supérieure (ÉTS)
Vue rue Peel

Director-Elect of Region 7 for the term 2003-2004:

W. O. (Bill) Kennedy, P.Eng., FEIC, Senior Member

IEEE Canada

Introducing the new Director-Elect of IEEE Canada

Bill can be contacted at: b7kennedy@shaw.ca

1.0 IEEE Activities

Bill Kennedy has been an active member of IEEE since 1970 and he has held executive positions at both the Region and Section levels. In 1993, he was the Secretary for Region Committee. In 1996, he assumed the position of Region Treasurer, a position he held until early 2000. During his term as Treasurer, he revised the financial model for Region 7 making it simpler to understand, developed the mechanism to fund projects and streamlined the budgeting procedures. He instituted the practice of the Treasurer presenting the Cheque Register to the Region Meetings for review and approval. To keep Region 7 in a strong financial position, he instituted a hedging mechanism against the US dollar. He was instrumental in the development of the project proposal mechanism for Region 7 and was an early supporter of the Translation Project.

Before his appointment as Region 7 Secretary, he was WCC Chair for 1991 and 1992. During this time, he was a member of the Volunteer Audit Committee, a committee that examined the administration and finances of the Region. Following that, he was appointed a member of the Forward Planning Committee for the Region and continued the activities of the audit committee.

Active in Section activities since 1983, he held various positions in Saskatchewan including, Secretary-Treasurer Saskatchewan Section (1983 -85), First Chair of South Saskatchewan Section (1985-87) - he was instrumental in effecting the amicable split of the Saskatchewan Section into two sections - North and South and Past Chair South Saskatchewan Section (1987-89). In 1990, he was appointed Chair WESCANEX'91 (1990-91) a successful joint venture conference with Region 7 and the North Saskatchewan Section. The surplus from the conference allowed the South Saskatchewan Section to establish its first Website.

His recent Section activities have included Interim South Saskatchewan Section Chair (1996-97). He was Secretary, Southern Alberta Section (2000-02) and was Co-Chair of the bid of the Southern Alberta Section for Sections Congress 2005. He has been the WCC Awards Chair since 1998.

At a technical level, he is a member of the Power Engineering Society and the Industrial Applications Society. Recently, he became active in the Power System Relaying Committee. In 1981, he was elected a Senior Member for the work he did on the testing of distance relays.

2.0 Education

Bill Kennedy received his B.Sc. (EE) from the University of New Brunswick in 1969. His education has been supplemented by graduate courses in Power System Engineering at the University of Manitoba and Ohio State University.

3.0 Work History

After graduation, he worked at Saint John Energy as a Junior Distribution Engineer where he was part of the design team that converted the existing overhead 4 kV distribution system in central Saint John to an underground 12 kV system.

In 1970, he joined The Shawinigan Engineering Company Ltd. of Montreal and moved to Winnipeg where he gained experience on the Nelson River HVDC transmission system in Manitoba. This was followed by work on the 500 kV Tarbella - Gatti Transmission Project in Pakistan where he was the Project Engineer responsible for the design of the substation control and protection. During this time, he was Project Manager for a 138 kV transmission project in Peru.

In 1977, he returned to Montreal and worked on projects in Newfoundland, Quebec, Ontario, Yugoslavia and Iran. In Newfoundland, he worked on a project involving the Bowaters Power Company and Bowaters Paper Company on their 50/60 Hz transmission system connecting the two companies. In Quebec, he worked on various projects involving the protection and control of industrial plants. In Ontario, he worked on the E.B Eddy Paper Mill between Ottawa and Hull. Before the Iranian revolution, he spent three months in Iran working on the 400 kV Bushere Nuclear Transmission Project where he was Resident Engineer Substations. In the former Yugoslavia, he worked on the power system for a pulp mill in Ivangrad.

In 1979, he joined SaskPower as the Lead Engineer responsible for the Protection Department. He developed the first System Protection Application Guide for the SaskPower transmission system. For work he did on the testing of distance relays, he was elected an IEEE Senior Member in 1981. He spent time in the Research and Development Centre where one of duties included the administration of six graduate level (M.Sc. and Ph.D.) scholarships at the Universities of Saskatchewan and Regina. Throughout his time with SaskPower, he held increasingly more responsible positions with his last position being Manager, Transmission and Interconnection Planning.

In 1996, he established a private practice as a consulting engineer specializing in the planning, operation and protection of electric power systems. During this time, he worked on projects in British Columbia, Alberta and Saskatchewan. In 1997, he began consulting for ESBI Energy of Houston, Texas and was part of the team that was instrumental in ESBI winning the Transmission Administrator position in Alberta.

In 1998, he joined ESBI Alberta Ltd. as Director, Measurement and Protection. ESBI Alberta Ltd. is the independent Transmission Administrator for Alberta. In his current position, he is responsible for all measurements on the Alberta Interconnected Electric System from revenue metering to fault recording.

4.0 Membership in Professional Associations

- Association of Professional Engineers and Geologists, Manitoba (1970 - present),
- Association of Professional Engineers and Geologists, Saskatchewan (1979 - present),
- Association of Professional Engineers, Geologists and Geophysicists of Alberta (1999 - present).

5.0 Publications

Author or co-author of eleven IEEE, CEA and Conference papers.

6.0 IEEE Awards

- Plaque recognizing his work as Chair of WESCANEX'91 (1991).
- WCC Edward F Glass Award (2000) - he was instrumental in having the WCC Merit Award renamed in honor of Ted Glass who was a mentor during his years in Winnipeg and Regina.
- Elected Fellow of the Engineering Institute of Canada (1998) “In recognition of his excellence in engineering and for services rendered to his profession and society.”

7.0 Biographical Sketch

Born in Windsor, Ontario, he has lived and worked in Saint John, NB; Montreal, QC; Winnipeg, MB; Regina, SW and currently lives and works in Calgary, AB. His wife is from Manitoba and they have three university-aged children.

Recent Advances in Video Compression Standards

by *Guy Côté and Lowell Winger,*
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Abstract

Video compression is a critical component of many multimedia applications available today. For applications such as DVD, digital television broadcasting, Satellite television, Internet video streaming, video conferencing, video security, and digital camcorders, limited transmission bandwidth or storage capacity stresses the demand for higher video compression ratios. To address these different scenarios, many video compression standards have been ratified over the past decade. This article first discusses the general structure and components of a standards-based video coding system. An overview of the emerging video coding standard H26L, currently being developed jointly by the ITU and ISO standard bodies, is then presented, highlighting key differences with its predecessor standards, such as MPEG-2, MPEG-4, and H.263.

Sommaire

La compression vidéo fait partie intégrale de plusieurs applications multimédia disponibles aujourd'hui. Pour certaines applications, par exemple les lecteurs DVD, la transmission de télévision numérique, la télévision par satellite, la transmission de vidéo par l'Internet, la vidéo conférence, la sécurité vidéo, et les caméras numériques, une bande de transmission limitée ou de la mémoire limité contribuent une demande pour des rapports de compression vidéo plus élevés. Pour adresser ces différents scénarios, plusieurs standards de codage vidéo ont été ratifiés durant la dernière décennie. Cet article discute en premier lieu la structure générale et les composantes d'un système de codage vidéo standard. Une description du standard émergent H.26L, qui est présentement en développement par les groupes de standardisation ITU et ISO, est présentée, soulignant les différences clés avec les standards précédant, tel que MPEG-2, MPEG-4 et H.263.20.

1.0 Introduction

Video compression is necessary for transmission of digital video over today's band-limited networks, or for storage constrained applications. For example, the transmission of digital video at 24 bit per pixel raw sampled at 720 by 480 spatial resolution and 30 frames per second (fps) temporal resolution[1] would require a bit rate of above 248 Mbps!

Compression of digital video without significant quality degradation is usually possible because video sequences contain a high degree of: 1) spatial redundancy, due to the correlation between neighbouring pixels, 2) spectral redundancy, due to correlation among the colour components, 3) temporal redundancy, due to correlation between video frames, and 4) psycho-visual redundancy, due to properties of the human visual system (HVS).

Removal of temporal redundancies in video signals accounts for a significant percentage of the achieved compression. Therefore, advanced techniques for the coding of the residual signal usually provide little additional compression as compared to traditional techniques, and additional complexity often does not justify this improvement. Rather than improving residual coding itself, most effective techniques attempt to reduce the residual to be coded, by improving the prediction of motion in a video sequence.

In recent years, interest in multimedia has generated a lot of research in the area of video coding in academia and industry alike and several successful standards have emerged, e.g. ITU-T H.261 [1], H.263 [2], ISO/IEC MPEG-1 [3], MPEG-2 [4] and MPEG-4 [5]. These standards address a wide range of applications having different requirements in terms of bit rate, picture quality, complexity, error resilience and delay, as well as improved compression ratios.

Here we first describe the block-based hybrid motion compensated and transform video coding method used by all video standards today. We briefly describe each component of such a system. The emerging H.26L [6] video coding recommendation is then described. We present the H.26L coding tools that differ significantly from previous video coding standards, and describe the performance of this standard in comparison to previous standards such as MPEG-2 and MPEG-4.

2.0 Block-based motion compensated and transform video coding

In the hybrid motion compensated and transform video coder, motion compensated prediction first reduces temporal redundancies. Transform coding is then applied to the corresponding difference frame to reduce spatial redundancies. For highly correlated sources, such as natural images, the compaction ability of the Discrete Cosine Transform (DCT) is very close to that of the optimal transform, the Karhunen-Loeve Transform (KLT). Moreover, the DCT, unlike the KLT, is data independent. This has made the DCT the most popular transform for image coding, as evidenced by its use in the JPEG still image international standard. Moreover, although motion compensated prediction difference frames are poorly correlated, the DCT is still the most popular transform for coding such frames. In fact, the DCT is used in all current video-coding standards.

In addition to removing temporal and spatial redundancies, psycho-visual redundancies are typically reduced as well. The most significant measure is a reduced resolution of colour detail in comparison to luminance detail to better match the characteristics of human perception. Video frames consist of three rectangular matrices of pixel data representing the luminance signal (luma Y) and two chrominance signals (chroma Cb and Cr) that correspond to a decomposed representation of the three primary colours associated with each picture element. Eight bits and 4:2:0 sub-sampling is the most common format used in video compression standards: the two chroma components are reduced to one-half the vertical and horizontal resolution of the luma component.

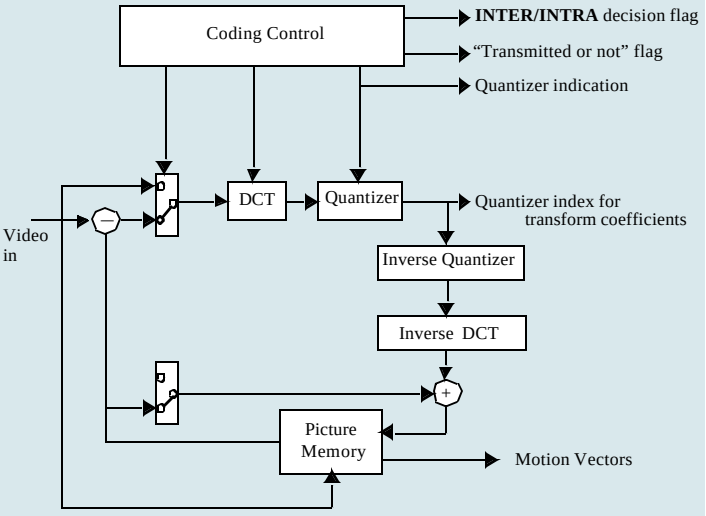

Figure 1: Block diagram of a block-based motion compensated and transform video encoder.

[1]: *720 x 480 pixels at 30 frames/second is the typical format used for broadcast television.*

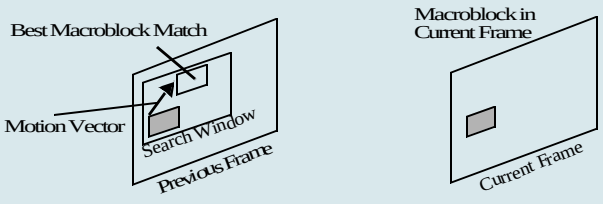

Figure 2: Example of motion estimation search window for a block matching algorithm.

A block diagram of a typical motion compensated prediction and transform video encoder is presented in Figure 1. In the next sections, we describe the building blocks of this video encoder.

2.1 Motion estimation and compensation

Each video frame is divided into macroblocks of equal size. Motion compensated prediction assumes that a block of pixels within the current picture can be modeled as a translation of a block from a previous picture, as shown in Figure 2.

Each block is normally predicted from the previous frame. This implies an assumption that each pixel within the block undergoes the same amount of translational motion. Two-dimensional displacement vectors or motion vectors represent this motion information. Due to the block-based picture representation, many motion estimation algorithms use block-matching techniques that obtain the motion vector by minimizing a cost function measuring the mismatch between a candidate block and the current block.

Although several cost measures have been introduced, the most widely used in motion estimation algorithms is the sum-of-absolute-differences (SAD), which computes the sum of pixel differences between the candidate reference block and the original block. To find the block producing the minimum mismatch error, we need to calculate the SAD at several locations within a search window. The simplest, but the most compute-intensive search method, known as the full search or exhaustive search method, evaluates the SAD at every possible pixel location in the search area. To lower the computational complexity, several algorithms that restrict the search to a few points have been proposed [7].

One motion vector per block is usually allowed for motion compensation. Sub-pixel motion estimation algorithms can provide a substantial improvement in reproduction quality. Most recent video coding standards allow both horizontal and vertical components of the motion vectors to be of half pixel accuracy. The range of representable motion vector values often limits the search window used in motion estimation. A positive value of the horizontal or vertical component of the motion vector represents a block spatially to the right or below the block being predicted, respectively.

Macroblocks can be predicted from previous frames only (P-macroblock), or from previous and/or future frames (B-macroblocks). The compression performance of B-macroblocks is superior to that of P-macroblocks, given the additional coding options. However, additional decoding delay is incurred, since the future P-frames must be decoded before temporally preceding B-frames can be decoded. A typical Group of Pictures is shown in Figure 3.

In current standards, motion compensation is usually performed on block sizes of 16x16 or 8x8 for P and B-macroblocks, and followed in the encoder by transformation as detailed in the next section.

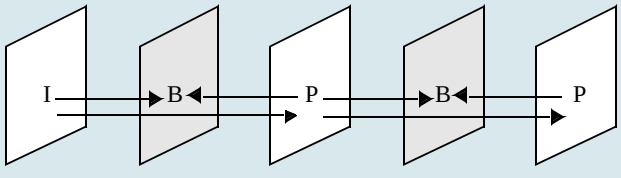

Figure 3: Typical arrangement of a Group of Pictures.

2.2 Transform

The purpose of the 8x8 DCT employed in all current video-coding standards is to de-correlate the 8x8 blocks of original pixels or motion compensated difference pixels and compact their energy into as few coefficients as possible. Besides its relatively high de-correlation and energy compaction capabilities, the DCT is efficient and amenable to software and hardware implementations. The most common algorithm for implementing the 8x8 DCT is 8-point DCT transformation of the rows followed by 8-point DCT transformation of the columns.

Although exact reconstruction of the original data can be theoretically achieved (inversion of the DCT transformation), it is often not possible using finite-precision arithmetic. While forward DCT errors can be tolerated, inverse DCT errors must meet a minimum level of precision in order to avoid IDCT mismatch between the reconstructed frames at the encoder and decoder.

The 8x8-DCT transform results in one DC coefficient and 63 AC coefficients. The DC coefficient is the mean or average of the transformed samples, representing the coarsest detail of the image block (the lowest spatial frequency). The AC transform coefficients represent finer image details (higher spatial frequencies).

In the encoder, transformation is followed by coefficient quantization, the stage at which loss of video detail is traded-off against the video compression ratio.

2.3 Quantization

The human viewer is more sensitive to reconstruction errors related to low spatial frequencies than those related to high frequencies. Slow linear changes in intensity or colour (low frequency information) are important to the eye. Sharp, high frequency changes can often not be seen and may be discarded. For every element position in the DCT output matrix, a corresponding quantization value is computed by dividing each DCT coefficient by a quantization parameter. The quantization parameter is the primary means by which the amount of compression and corresponding reduction in fidelity of the compressed video are controlled. The net effect is usually a reduced variance between quantized coefficients as compared to the variance between the original DCT coefficients, as well as a reduction of the number of non-zero coefficients, which improves the efficiency of the entropy coding, described in the next section.

2.4 Entropy coding

Entropy coding reduces the average number of bits used to represent the compressed video through the use of means such as variable length codes (VLCs). VLCs are often generated with Huffman codes such that shorter codewords are used to represent more frequently occurring symbols (such as small coefficient values). Arithmetic coding can also be used as means of entropy coding. Other information, such as prediction types and quantizer indication, is also typically entropy coded by means of VLCs or arithmetic codes.

Prior to entropy coding, motion vectors are usually predicted by component values set to the median value of three neighbouring already transmitted motion vectors: the motion vectors of the blocks to the left, above and above right of the current block. The difference motion vectors are then entropy coded.

Prior to entropy coding, the quantized DCT coefficients are arranged into a one-dimensional array by scanning them in zig-zag order. This rearrangement places the DC coefficient first in the array and the remaining AC coefficients are ordered from low to high frequency. The rearranged array is coded using a 3-dimensional run-length VLC table, representing the triple (LAST, RUN, LEVEL). The symbol RUN is defined as the distance between two non-zero coefficients in the array. The symbol LEVEL is the non-zero value immediately following a sequence of zeros. The symbol LAST is equivalent to the End-of Block flag also employed in 2-dimensional run-length coding, where “LAST = 1” means that the current code corresponds to the last coefficient in the coded block. This coding method produces a compact representation of the 8x8 DCT coefficients, as a large number of the coefficients are normally quantized to zero. Ideally, the re-ordering results in the grouping of long runs of consecutive zero values.

2.5 Coding control

The two switches in Figure 1 represent the intra/inter mode selection.

Such a selection is usually made at the macroblock level. The performance of the motion estimation process, usually measured in terms of the associated distortion values, can be used to select the coding mode. The coding mode where temporal prediction is used is called the inter mode. This mode is selected if the motion compensation process is effective, and only if the prediction error macroblock - the difference between the original macroblock and the motion compensated predicted macroblock - need be encoded. If temporal prediction is not used, the corresponding coding mode is called the intra mode. If a macroblock does not change significantly with respect to the reference picture, an encoder can also choose not to encode it, and the decoder will simply repeat the macroblock located at the subject macroblock's spatial location in the reference picture. This coding mode is referred to as skip. More sophisticated coding mode selection algorithms based on rate-distortion (RD) optimization methods can also be used, as discussed in the next section.

2.6 Rate-Distortion Optimized Video Coding

A key component in high-compression lossy video coding is the operational control of the encoder, through the motion estimation process, quantization step size selection, and the video coding mode selection. The process of selection between different possible representations with varying rate-distortion efficiencies can be optimized using Lagrangian minimization techniques based on rate-distortion theory [8], which are briefly described in this section. At the source coding level, rate-distortion theory sets limits on the achievable output distortion for a given coder output rate, or conversely, sets limits on achievable output rate for a given output distortion.

In video coding, the coding modes of operation are generally associated with signal-dependent rate-distortion characteristics, and rate-distortion tradeoffs are inherent in the coding parameters selection process. The optimization task is to choose, for each image block, the most efficient coded representation in the rate-distortion sense. This task is complicated by the fact that the various coding options show varying efficiency at different bit rates and with different scene content. For example, inter coding is efficient in representing key changing content in image sequences. However, intra coding may be more efficient in a situation where the block-based translational motion model cannot accurately represent the image sequence changes. For low activity regions of the video sequence, simply using the skip mode may be preferred. By allowing multiple modes of operation, we expect improved rate-distortion performance if the mode selection method is applied judiciously to different spatio-temporal regions of a video sequence.

The goal of the video compression system is to achieve the best fidelity (or the lowest distortion D) given the capacity of the transmission channel, subject to the coding rate constraint R(D). This optimization process can be solved using the Lagrangian multiplier method where the distortion term is weighted against a rate term. The Lagrangian formulation of the minimization problem is such that we minimize:

$J = D + \lambda R$, for a particular Lagrangian parameter λ. Each solution for a given value of the Lagrangian parameter λ should correspond to a locally optimal solution for a given rate constraint. A given value of λ represents a specific point on the operational rate-distortion curve. It is possible to obtain an approximate relation between the quantizer step size Q, which controls the output bit rate, and the optimal value of λ. This is particularly useful when a rate control method is used to achieve a particular video encoder bit rate.

3.0 Commonalities in the Emerging H.26L Recommendation

The elements common to all video coding standards that are discussed in the preceding sections are also present in the emerging H.26L recommendation, which is anticipated to become the newest international video-coding standard in early 2003. In summary, the following elements are present in the current H.26L recommendation: macroblocks are 16 lines by 16 pixels; luminance is represented with higher resolution than chrominance with 4:2:0 sub-sampling; motion compensation and block transforms are followed by scalar quantization and entropy coding; motion vectors are predicted from the median of the motion vectors of neighbouring blocks; bi-directional B-pictures are supported that may be motion compensated from both temporally previous and subsequent pictures; and a direct mode exists for B-pictures in which both forward and backward motion vectors are derived from the motion vector of a co-located macroblock in a reference picture. In the following sections, coding blocks of the emerging H.26L recommendation are compared and contrasted with other recent standards.

3.1 Intra prediction

H26L provides means to spatially predict intra-coded macroblocks. With these advanced prediction modes, the performance of intra-frame compression in H26L is similar to that of the recent still image compression standard, JPEG-2000. H263 and MPEG-4 also provide intra prediction. The differences between H26L and H.263 (and MPEG-4) are that the prediction is in the pixel domain, as opposed to the frequency domain, and sub-block level prediction modes are available, as opposed to only macroblock modes.

Intra coded macroblocks (in intra- or inter-frames) may use either 16x16 or 4x4 spatial prediction modes for luma. Three sub-modes are available with 16x16 prediction. A 16x16 macroblock can be predicted from the previously adjacent decoded pixels that are available due to the raster order (from the top-left with left-to-right swaths) decoding of macroblocks: vertical prediction from pixels above, horizontal prediction from pixels to the left, and plane prediction by spatial interpolation between the two sets of pixels.

Nine sub-modes are available with 4x4 prediction. A 4x4 sub-block can be predicted from the previously adjacent decoded pixels that are available due to the raster order decoding of each 8x8 block within a macroblock, and the nested raster order decoding of each 4x4 sub-block with each 8x8 block. Due to this decoding order, not all of the 4x4 prediction modes will always have decoded pixel data available in their desired prediction direction. In this case, the closest available decoded pixel data is used. The intra prediction modes are the following: DC prediction from the mean of adjacent pixels above and to the left, vertical (down) prediction from pixels above, horizontal (left) prediction from pixels to the right, diagonal (down-left) from pixels above and pixels to the right, diagonal (down-left) from pixels above and to the left, and four off-diagonal modes (+/- 22.5 degree predictions: left-of-vertical, right-of-vertical, up-from-horizontal, and down-from-horizontal).

3.2 Motion estimation and compensation

The H.26L recommendation supports the use of multiple different reference pictures from which prediction of inter macroblocks and blocks can be made. Multiple reference pictures may help prediction of transitionally covered background and periodic non-translational motion.

As in MPEG-4, ¼-pel motion compensation is used for temporal prediction. Six-tap interpolation filtering for the ½-pel positions is followed by bi-linear interpolation to derive the ¼-pel positions. A new feature is the existence of a funny position that is filtered more heavily to support instances in which only the coarse details, and not the high spatial frequencies, of current picture are accurately predicted by the reference picture. In addition, eight-tap interpolation filtering for 1/8-pel positions is optionally available.

As with. H.263 and MPEG-4, the model for motion compensation is variable-size block translation with motion vectors that may extend outside the picture boundaries by extending boundary pixel values to outside the frame. However, a larger variety of block sizes are now available for motion compensation. Each 16x16 macroblock may be divided horizontally and/or vertically for the purpose of motion compensation. If a macroblock is partitioned both horizontally and vertically, resulting in four 8x8 blocks, then each of those 8x8 blocks may also be partitioned horizontally and/or vertically. In this way, up to 16 motion vectors may be transmitted for a macroblock. The common partitioning of a 16x16 macroblock and of an 8x8 block is shown in Figure 4.

Macroblocks in inter-frames (P-frames or B-frames) may be coded as skipped, direct mode (B-frames only), intra 4x4 spatial prediction, or motion compensated with up to 16 motion vectors and with the possibility of optionally coding each 8x8 sub-block with intra 4x4 prediction.

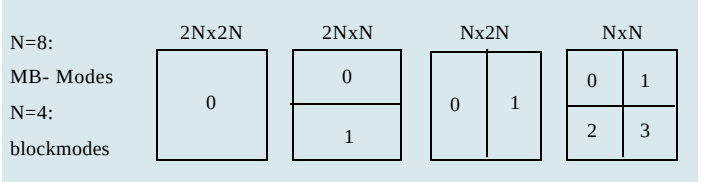

Figure 4: Available macroblock partitionning in H.26L.

Each 8x8 sub-block may predict from a different reference frame.

Post-filtering for the removal of blocking and ringing artefacts is known to be a critical element for obtaining high perceptual quality with current standards. With the H.26L recommendation, the ringing artefact is alleviated through the use of a shorter 4-point transform. Adaptive deblocking filtering is moved into the coding loop such that temporal prediction is based on the superior filtered reconstructed (decoded) images.

Conventional television is broadcast in interlaced format where a picture frame is divided in two picture fields that are displayed at a different time interval. The temporally first picture field (called top or odd field) is displayed on every odd line of a picture frame, and the second picture field (called bottom or even field) is displayed on every even line of a picture frame. The two fields form the picture frame. Interlaced material benefits from separate motion compensation and transformation in the different video fields when large motion is present. In H.26L, adaptive switching between separate and combined fields is supported at the picture level, rather than at the macroblock level, as previously supported by MPEG-2.

3.3 Transform & Quantization

A 4x4 integer "pseudo-DCT" transform replaces the previously common 8x8 DCT transform for de-correlating the pixel prediction residuals. The shorter transform length becomes more competitive with the longer transform due to the improved prediction modes for pixel luma. The benefits of the new transform are the complete elimination of inverse transform mismatch, which would lead to encoder/decoder mismatch in previous standards, improved perceptual quality, and lower complexity.

The 4x4 transform is expanded to a more traditional 8x8 transform for chroma and 16x16 luma predicted blocks through the use of a second 2x2 transform acting on the DC coefficient of 4x4 transformed blocks in a 4:2:0 macroblock. Similar to H.263 Annex T, a smaller step size is used for the quantization of chroma samples to improve chroma fidelity.

3.4 Entropy Coding

In contrast to other recent video coding standards, one universal table of variable length codes is available for VLC entropy encoding. Simplification is achieved by mapping each symbol to the VLC codeword that is appropriate given its frequency in the bitstream, rather than the more common approach of constructing separate VLC tables for each of the symbols sets (motion vector prediction residuals, run-levels, (macroblock modes, etc.).

As a higher complexity, higher performance alternative to VLC entropy coding, context-based adaptive arithmetic coding (CABAC) may be used. An arithmetic code is more efficient than a VLC for symbol probabilities that are much greater than 50%, since it permits a symbol to be represented with less than one bit. Adaptive codes reduce the inefficiency of non-stationary symbol statistics caused by mismatch between static codeword lengths and symbol probabilities that change due to bitrate, type of motion present in the source, and other factors. Context modelling provides estimates of the conditional probabilities of the symbols. The sophistication of the contexts defined with CABAC substantially improves upon the syntax-based arithmetic coding (SAC) optionally available with H.263.

3.5 Coding Control

Improvements in video compression with recent standards have often been fairly predictably achieved through the use of a larger number of choices. A much larger number of possible coding modes are available in the H.26L standard than in previous standards. As the number of coding choices increases, searching and rate-distortion optimization as tools for decision-making in the encoding process, as discussed in Section 2.5, become increasingly important.

4.0 Relative Performance and Conclusion

This survey of the emerging H.26L recommendation has compared key differences that lead to increased compression performance in comparison to previous standards. Compression improvement of up to 50% over the best previous standards is the primary motivation for advancing the new H.26L recommendation. Although storage and bandwidth are continuously growing, increasing demand for higher resolutions and more simultaneous streams with existing and emerging communications channels and storage media will continue to fuel the demand for greater compression performance.

5.0 References

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About the authors

Guy Côté holds a Ph.D. in Electrical and Computer Engineering from the University of British Columbia and a B.A.Sc. in Electrical Engineering from the Royal Military College of Canada.

Guy is a co-founder and VP R&D at VideoLocus. Prior to VideoLocus, Guy developed video coding algorithms for PixStream Inc., which was acquired by Cisco Systems in December 2000. His work at PixStream/Cisco included research on different aspects of video coding standards including MPEG-1, MPEG-2, MPEG-4, and H.263.

He is an active participant in the ITU-T Video Coding Experts Group (VCEG) and a voting member of the International Standardization Committee ISO/IEC/JTCI/SC29 (JBIG, JPEG, MPEG). Guy has published over 25 papers and standards contributions and has four patents pending in the area of video compression.

Lowell Winger holds a Ph.D. in Electrical and Computer Engineering from the University of Toronto, a M.A.Sc. in Systems Design Engineering and a B.A.Sc. in Systems Design Engineering from the University of Waterloo, and is a licensed Professional Engineer.

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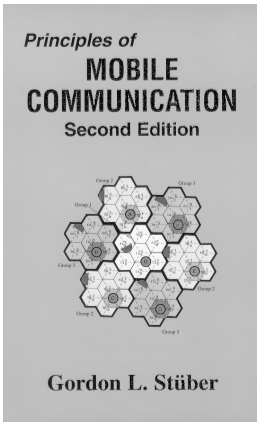
He is also currently an Adjunct Professor for the Dept. of Systems Design Engineering at the University of Waterloo, an active participant in the IEEE (Institute of Electrical and Electronics Engineers), and a voting member of the International Standardization Committee ISO/IEC/JTCI/SC29 (JBIG, JPEG, MPEG).

Principles of Mobile Communication



by Gordon L. Stuber,
Second Edition,
ISBN 0-7923-7998-5,
Published in 2001, 752 pages,
by Kluwer Academic Publishers.

Book Reviewed by Zongsen Wu, Shaowen Song and Jian Shu,
Physics and Computing Department, Wilfrid Laurier University, ON

Wireless systems and services have undergone a remarkable development since the first cellular system was introduced in the early 1980s. There have been quite a few books on the topic since then. This book differs from others on the subject by focusing on mathematical modeling and theoretical analysis. As the title suggests, the book stresses the fundamentals of mobile communications engineering that are important to any mobile communication systems rather than the systems or devices themselves.

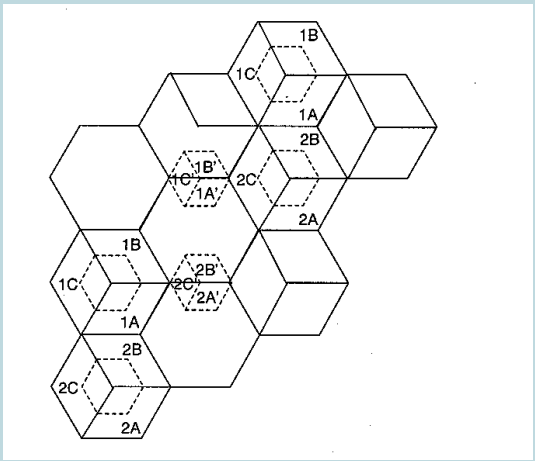
This book, following its first edition, provides thorough and up-to-date treatment of wireless physical communications. The book is divided into thirteen chapters and one appendix, and is 752 pages cover-to-cover.

Chapter 1 begins with an overview, which introduces a broad array of issues relating to wireless communication. Readers can find a description of various wireless systems and services, basic concepts of cellular frequency reuse, and the link budget for cellular radio systems. Mobile radio propagation environment, co-channel interference and noise are briefly discussed in this chapter as well.

Chapter 2 deals with the propagation modeling. It begins with a summary of propagation models for narrow-band and wide-band multipath channels, and then provides a discussion of channel simulation techniques that are useful for radio link analysis. Discussions on the shadowing and path loss models are also presented in reasonable detail.

In Chapter 3, a detailed treatment of co-channel interference, the primary impairment in high capacity cellular system is provided. The author discusses here four types of interference respectively.

Chapter 4 deals with various types of modulation schemes that are used in mobile communication systems along with their power spectral densities. Readers can see QAM, PSK OFDM and CPM are included in such modulations.



Overlaid inner cells can be used to maintain the frequency reuse constraint when cell splitting is used. (Figure 10.13 of the book on page 531)

In Chapter 5, the performance of digital signaling on the narrow-band flat fading channels with a variety of receiver structures is presented. Error probabilities of PSK, M-QAM, Orthogonal Signals, OFDM and MSK are discussed respectively.

Chapter 6 provides a treatment of antenna diversity techniques. Several signal combining methods, including selective, maximal ratio, equal gain and switched methods, are discussed in the chapter.

Chapter 7 provides an extensive treatment of digital signaling on the fading ISI channels that are typical of mid-band land mobile radio systems. The Chapter begins with the characterization of ISI channels and goes on to discuss techniques for combining ISI based on symbol-by-symbol equalization and sequence estimation and co-channel interference cancellation.

Chapter 8 deals with bandwidth efficient coding technique. The chapter begins with a discussion of basic block and convolutional coding. It then goes on to a detailed discussion on the design and performance analysis of convolutional and trellis codes for additive white Gaussian noise channels, and interleaved flat fading channels. The chapter concludes with an introduction of Turbo coding.

Chapter 9 describes spread spectrum. The chapter begins with an introduction to direct sequence and frequency hop spread spectrum. This is followed by a detailed treatment of spread sequences. Also included is a discussion of the effects of tone interference on direct sequence spread spectrum, and the RAKE receiver performance on wide-band channels. The chapter wraps up with a discussion of the error probability of direct sequence code division multiple access.

Chapter 10 discusses TDMA cellular architectures. It begins with an introduction of conventional TDMA systems and how they are evolved to meet traffic growth. This is followed by hierarchical overlay/underlay architecture. Finally, the chapter wraps up with macrodiversity TDMA architecture.

Chapter 11 is the counterpart of Chapter 10 and considers issues that are relevant to cellular CDMA, such as capacity estimation and power control.

Chapter 12 covers the important problem of link quality evaluation and handoff initiation, and handoff performance, in cellular system.

Chapter 13 provides an interview of the various channel assignment techniques that have been proposed for FDMA and TAMA cellular system.

In summary, this book provides a thorough and up-to-date mathematical treatment and theoretical analysis of wireless communications. The mathematical treatments are well displayed by the author. The derivations are usually initiated from the very beginning, which provides great help to the reader to understand the entire mathematical development. Given the contents of this book, it requires the reader to have sufficient mathematical background, especially in the areas of advanced calculus, partial differential equations, matrix operations, and probably some graph theory. Although the book is intended for graduate students, it can be used as a textbook for senior undergraduate courses. Besides the contents and beautiful mathematical displacement, the book is also professionally edited with well-illustrated graphs. We would have preferred to have the references at the end of each chapter rather than at the end of the book, which provides readers with an easy access to the references related to specific topics. Providing the solutions to some of the problems may also be helpful for the self-studying type of readers.

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ENGINEERING INSTITUTE OF CANADA

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Présentés lors du Banquet de I'ICI le samedi 2 mars, 2002

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