

# Management and Services

edited by

**Dr. Md. Mamun Habib**

**SCIYO**

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Edited by Dr. Md. Mamun Habib

### **Published by Sciyo**

Janeza Trdine 9, 51000 Rijeka, Croatia

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**Publishing Process Manager** Ana Nikolic

**Technical Editor** Martina Peric

**Cover Designer** Martina Sirotic

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First published September 2010

Printed in India

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Additional hard copies can be obtained from [publication@sciyo.com](mailto:publication@sciyo.com)

Management and Services, Edited by Dr. Md. Mamun Habib

p. cm.

ISBN 978-953-307-118-3

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# Preface

**Management** in all business areas and organisational activities are the acts of getting people together to accomplish desired goals and objectives. **Service** is intangible, therefore, it is not too easy to define the theory application in varieties of service industries. **Service Management** usually incorporates automated systems along with skilled labour; it also provides service development. Due to enormous demand of service industries and management development, the Book entitled “**Management and Services**” would create a milestone in management arena for all categories of readers including Business Administration, Engineering and Architecture. This book covers educational service development, service-oriented-architecture and case research analysis, including theory application in network security, GRID technology, integrated circuit application.

This book is comprised of five chapters and has been divided into two parts. Part A contains chapters on service development in educational institutions. This part depicts the application of supply chain management concept in service industries like tertiary educational institutions and multiple ways of web 2.0 applications transforming learning patterns and pathways. To understand the subject in a practical manner, Part B of this book consists of noteworthy case studies and research papers on management and services. This part represents theory application of Data mining, Fuzzy Cluster, Game theory, GRID Technology, simulation of Operational Amplifier and Current Controlled Conveyor II in network security, architecture, and integrated circuit application. This section will certainly unveil a wide variety related to management and services.

**Chapter 1** describes an empirical study that addresses the education supply chain, the research supply chain, and educational management as major constituents in an Integrated Tertiary Educational Supply Chain Management (ITESCM) model. This chapter highlights conceptual framework, model evaluation by Structural Equation Modeling technique through AMOS, the latest statistical tool. The ITESCM model furnishes stakeholders of the supply chain with appropriate strategies to review and appraise their performance toward fulfillment of ultimate goals, i.e. producing high-caliber graduates and high-impact research outcomes, which represent two main contributions, for the betterment of the society. Finally, the author rectifies application guidelines based on the research findings for current university administrators and prospective investors.

In **Chapter 2**, Web 2.0, a service-oriented-architecture, describes the evolving use of the internet as a technology platform to enhance functionality, communication and collaboration. The multiple ways of web 2.0 applications are transforming learning patterns and pathways, or more exactly, all the advantages, opportunities and challenges for learning in educational institutions.

The method presented in the **Chapter 3** constitutes a novelty in validating security Nonfunctional Requirement (NFR). The author applies Game theory to assess the security NFR of a prospective network prior to its implementation and as such provide a validation of the security NFR. This chapter presents a novel game-theoretic approach to security requirements validation that contributes towards network security quantification.

A pilot platform Resource and Environment Geo-Information Sharing on web services based on a case study is described in **Chapter 4**. Grid technology is developed for general sharing of computational resources and not aware of the specialty of geospatial data. Spatial Information Grid (SIG) is the fundamental application of Grid technology in spatial information application service domain.

**Chapter 5** describes the proposed architecture that is composed of only two fundamental active building blocks, i.e. an Operational Amplifier (OA) and a Current Controlled Conveyor (CCC) II making the approach convenient for further integrated circuit implementation with systematic design and dense layout. The simulation results are in close agreement with the theoretical prediction verified by the usefulness of the proposed design approach in current mode operations.

I would like to say heartiest thanks to all authors who have contributed their valuable research papers, articles and case studies to produce this excellent compilation. Finally, I express my gratitude to Almighty Allah for the successful completion of this book in scheduled time.

Editor

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# **An empirical research of ITESCM (integrated tertiary educational supply chain management) model**

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## **1. Introduction**

In the service industry, service providers have an incentive of getting better quality inputs from customer-suppliers, and customer-suppliers have an incentive of getting better quality outputs from the service provider. Supply Chain Management (SCM) is needed for various reasons: improving operations, better outsourcing, increasing profits, enhancing customer satisfaction, generating quality outcomes, tackling competitive pressures, increasing globalization, increasing importance of E-commerce, and growing complexity of supply chains (Stevenson, 2002).

Supply chain management helps the business organization to compete in the dynamic global market. The goal of supply chain management is to integrate activities across and within organizations for providing the customer value. This should also be applicable to the academia, which represents a type of non-profit organizations. The goal is to provide the society value by producing high quality graduates and quality research outcomes. (Habib & Chamnong, 2008a).

Supply Chain Management (SCM) in the manufacturing industry is a very common scenario. However, SCM in the service industry especially in higher educational institutions is receiving more attention. This exploratory study addresses the education supply chain, the research supply chain, and educational management as major constituents in an Integrated Tertiary Educational Supply Chain Management (ITESCM) model. Its applicability was successfully verified and validated through survey data from leading tertiary educational institutions around the world. The proposed model was developed based on the analysis of literature, past theoretical frameworks, interviews with stakeholders. Model constructs were identified and confirmed by 493 respondents, representing university administrators, faculty and staffs, employers, and graduates. The resulting model was subsequently evaluated for accuracy and validity by multiple linear regression (MLR) analysis and the structural equation modeling (SEM) technique.

The study revealed education development, education assessment, research development, and research assessment as four main activities in educational management. Four aspects of each activity, namely programs establishment, university culture, faculty capabilities, and

facilities were investigated at strategic, planning, and operating levels. MLR equations of different separate models were mathematically formulated and eventually synthesized into an overall model.

The ITESCM model furnishes stakeholders of the supply chain with appropriate strategies to review and appraise their performance toward fulfillment of ultimate goals, i.e. producing high-caliber graduates and high-impact research outcomes, which represent two main contributions, for the betterment of the society.

This chapter attempts to develop a model for successful educational supply chain. The research focuses on the universities. The researcher investigates numerous literatures on supply chain management to shed lights on educational supply chain components and how they may be operated and coordinated to achieve the goals. The desirable goals may be quality graduates and quality research outcomes. The ultimate goal of a successful educational supply chain is, however, the improved well-being of the society (Habib & Chamnong, 2008b).

## 2. Literature Review

Based on findings from literature review, the researcher found a large number of papers and articles in supply chain management. Most of them investigated supply chain management in the manufacturing sector (Udomleartprasert & Jungthirapanich, 2004; Ballou, 1978; Ballou, 2007; Heskett, 1964; Heskett, 1973; Stevenson, 2002; Cigolini, 2004; Oliver, and Webber, 1992; Lummus and Robert, 1999; Gripsrud, 2006; Tan and et al., 2002; Udomleartprasert and Jungthirapanich, 2003, Hart, 2004; Jones and Riley, 1985; Jones, 1989; Houlihan, 1988; Stevens, 1989; Scott and Westbrook, 1991; Watts and et al. 1992; Lee and Billington, 1992; Inman and Hubler, 1992; Cooper and et al. 1993; Londe and et al. 1994; Londe and Bernard, 1997; Lee and et al. 2007)

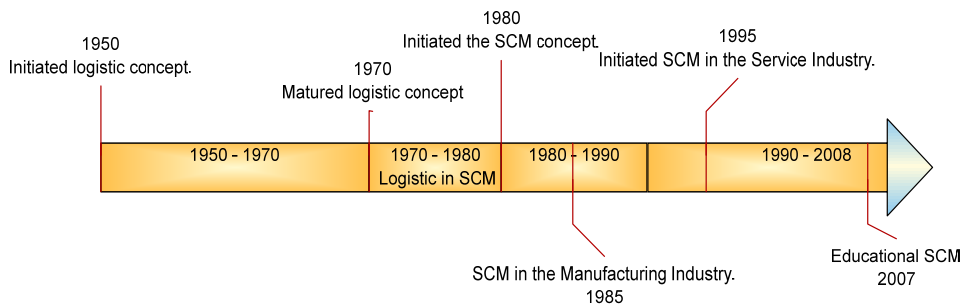


Fig. 1. Evolutionary timeline of supply chain management

Only a few addressed issues in SCM for the service industry (Dibb and Simkin, 1993; Sampson, 2000; Nixon, 2001; Sengupta and Turnbull, 1996; Fernie and Clive, 1995; Kathawala and Khaled, 2003). Very few focused on educational supply chain management. Just two papers (Lau, 2007; O'Brien and Kenneth, 1996) were found to be relevant to the educational supply chain management. The evolutionary time line of supply chain management has been depicted in Figure 1.

Education, being part of the service industry, is characterized differently from the manufacturing industry as its product, i.e. knowledge, is intangible. Effective education relies much on its personnel's knowledge, experience, and ethics. Supply chains are quite easy to define for manufacturing organizations, where each participant in the chain receives inputs from a set of suppliers, processes those inputs, and delivers them to a distinct set of customers. With educational institutions, one of the primary suppliers of process inputs is customers themselves, who provide their bodies, minds, belongings, or information as inputs to the service processes. We refer to this concept of customers being suppliers as "customer-supplier duality." The duality implies that educational supply chains are bi-directional, which is that production flows in both directions (Sampson, 2000).

In educational supply chain, a university works in close collaboration with schools, further education colleges, its current students, university staff, and employers of its graduates in designing curricula (Heskett, 1964) to ensure that the needs of all stakeholders are satisfied. Educational supply chain has customer driven vision that can produce a number of competitive advantages for the supply chain by helping improve productivity, boosting customer satisfaction, producing quality outcomes. Increasingly, many end products are recognizing the potential benefits of partnering with their suppliers in managing quality in their supply chains.

In the educational supply chain, there are direct and indirect student services to process the raw material, i.e. the student. Direct student services include student design and development, student sourcing and selection, student academic and non-academic trainings, student practical trainings, student result testing and finally student further development. The indirect student services are campus advancement and maintenance, IT infrastructure, hostel, clearances, bookstore, security, restaurants and sport facilities, etc. (Lau, 2007).

Every student should be designed and developed critically. A student should be assigned a faculty member, who supervises the student development process throughout the supply chain. It is because the student is non-identical and the university cannot set up one supply chain process for all the students. In the integrated SCM, customized supply chain processes for each student is suggested to ensure the student quality (Habib, 2009b).

Research is expensive and long-term requiring customized and responsive supply chain to satisfy the customer. For example, if there is an applied research to develop a specific IT system for an industry, the supply chain should be used to search for all the relevant operators, who are professional in developing the IT system, and the facilitates, which can execute the research faster. On the other hand, if there is a basic research to develop a few social observations through survey as a mean to gather relevant data, the supply chain should be managed to communicate the professionals and facilities in the university so as to prevent duplicated research scope and to streamline the survey time and cost (Habib & Jungthirapanich, 2009a).

According to the concept of three decision levels in SCM, this concept would be adopted for the higher educational institutions (Harris, 1998).

**1. Strategic Level:** Strategic level decisions are the highest level. Here a decision concerns general direction, long-term goals, philosophies and values. These decisions are the least structured and most imaginative; they are the most risky and of the most uncertain outcome, partly because they reach so far into the future and partly because they are of such importance.

**2. Planning Level:** Planning level decisions support strategic decisions. They tend to be medium range, medium significance, with moderate consequences.

**3. Operating Level:** Operating level decisions are every day decisions, used to support planning level decisions. They are often made with little thought and are structured. Their impact is immediate, short term, short range, and usually low cost. The consequences of a bad operational decision will be minimal, although a series of bad or sloppy operational decisions can cause harm. Operational decisions can be pre-programmed, pre-made, or set out clearly in policy manuals.

To accomplish proper teaching and research works in the universities; different factors have to need analyzed. Four factors, namely faculty capabilities, facilities, programs establishment, university culture (Lau, 2007; Habib and Jungthirapanich, 2008b, 2009a, 2009c, 2010a) will be illustrated in this section.

**Programs Establishments (PE):** Programs establishment would be occurred for the education and research in terms of development and assessment in the universities. Universities design different programs, to enhance the diversification in education development and establish various programs to assess the development. Universities also intend different programs to increase the diversification in research development and research assessment. Universities have to attempt product differentiation, i.e. programs establishment. With the growing number of establishments attaining university status, this issue should be appearing on each program director's agenda. Hands-on experience, industrial placements, social demand, provision of IT facilities, and innovative academic methods all demonstrate attempts to differentiate programs establishment (Kotler and Bloom, 1984).

**Faculty Capabilities (FC):** Faculty members establish good communication, provide rich environment for classroom observation, model best practices, create opportunities for reflection, and support students' participation in curriculum planning, teaching and research. Traditionally, university faculty members are evaluated according to the three major criteria: teaching, research, and services (Comm and Mathaisel, 1998).

**University Culture (UC):** The concept of organizational culture would be applicable for the universities by the name of University Culture. However, the type of the university culture will fully depends on the university management or administrator. In fact, university culture is the personality of the university (Habib, 2009b).

**Facilities (FA):** Universities offer a wide range of modern facilities to their students. These include state of the art lecture halls, libraries, laboratories and IT services to ensure that students are provided with an environment in which they can learn, both successfully and comfortably. Lecture rooms are principally conducted using state-of-the-art distance learning technology, online education, e-learning via Internet. Online databases, e-journal, digital library, etc. represents modern research facilities in the universities (Habib, 2009b)

One of the main goals of an educational supply chain is to improve the well-being of the end customer or the society. To achieve this goal, educational institutions need to have a certain degree of knowledge about the partners in their supply chains including suppliers, customers, and the consumer. The performance of the supply chain management depends on the seamless coordination of all supply chain stakeholders to ensure attainment of desirable outcomes (Habib and Jungthirapanich, 2010b).

### 3. Research Methodology

The questionnaire was developed and analyzed to determine reliability and validity of the tools. Reliability is the correlation of an item, scale, or instrument with a hypothetical one, which truly measures what it. Fifty-seven variables were identified and studied to assess the extent to which academicians and the practitioners are practiced in the academia. Supply chain relationships among model constituents, e.g. suppliers, the universities, customers, and the society were also investigated. In the scale reliability test, the Cronbach's alpha value is 0.961, which means the scale is excellent reliable (Ebel, 1951) and could be used to test the content validity. Validity of the variables was confirmed by experts, as well as academicians. The researcher applied non-probability sampling techniques based on the judgment (purposive) sampling. This judgment sampling depends on the personal judgments from all stakeholders of the universities, including university administrators, faculty, staffs, graduates, employers, etc.

The respondents were asked to indicate the level of significance after supply chain implementation using five-point Likert scale (1 = strongly disagree, 5 = strongly agree) (Cutler, 1998). The researcher used interval scale, statistical parametric scale, for the survey research questionnaire. The researcher conduct a survey among all stakeholders, including experts in university administration, employers, graduated students, etc. The questionnaires were pre-tested to check the content validity and revised where necessary to ensure the content validity.

In pretest, all the respondents were academicians of top ranked different universities in the world. The 54 filled questionnaires are analyzed, the result shown the excellent in reliability questions as all constructs reliability result are higher than 96%. For the large-scale research, the surveys were collected, totally 493 from all stakeholders through email and self-administered, out of 3421 respondents (14.41% are usable) to obtain maximum likelihood estimates of standardized regression weights, correlations (Arbuckle, 2005) etc. Among them, 174 respondents were experts, faculty, staff of the Universities, 166 respondents were graduates, and 153 respondents were employers.

From the hypotheses, the Structural Equation Modeling (SEM) has been utilized to answer the research questions. The growing interest SEM techniques and recognition of their importance in empirical research are used to test the extent to which the research meets recognized standards for high quality statistical analysis (Strub and et al., 2002; Udomleartprasert and Jungthirapanich, 2003). The interrelationships among all educational supply chain components are investigated and confirmed by SEM technique. The researcher used latest statistical powerful software AMOS (Analysis of Moment Structures) for SEM.

### 4. ITESCM Model Development

This study attempts to develop an empirical research model based on both primary and secondary data. Once the existing body of literature has been thoroughly investigated, a conceptual framework is proposed. The conceptual model is developed based on the analysis of past theoretical frameworks. O'Brien and Kenneth (1996) reported the results from a survey conducted among students and employers. There was no research model in that paper. Lau (2007) performed an in-depth case study approach to developing an educational supply chain as the 'student' and the 'research' supply chain for the City University of Hong Kong. This case study was weak to generalize through a single case approach.

The researcher develops a conceptual framework of educational supply chain for the universities. The resulting model is finally evaluated for accuracy and validity through the Structural Equation Modeling (SEM) technique (Habib, 2009; Habib & Jungthirapanich, 2010b). For providing the clear conception of the conceptual framework, the researcher depicts holistic view of educational supply chain in Figure 2. In this supply chain, raw materials are students as well as internal and external projects. Finished products are graduates and research outcomes (Habib and Jungthirapanich, 2009d). In this framework, single-level, bi-directional simplified form of supply chain management has been formulated for the universities, as shown in Figure 3. In the higher educational institutions, since a single party is unable to do anything, the researcher involves different parties to achieve final outcomes. Customers can closely monitor the value added by service providers. When customers supply major inputs, they know exactly what condition those inputs are. Then, when they subsequently receive the output from the service provider, they can easily assess the amount of value added by the service provider.

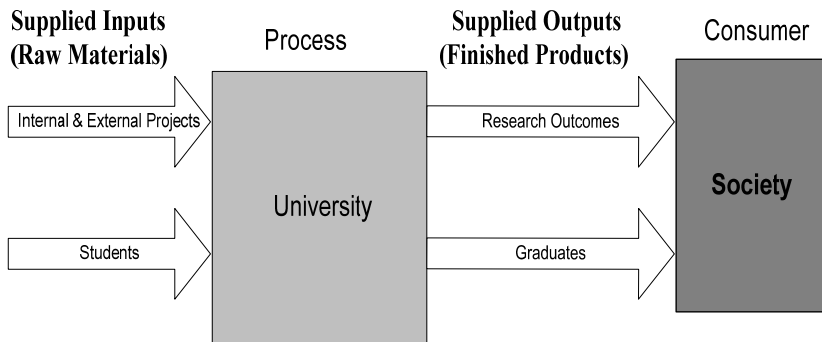


Fig. 2. Holistic view of educational supply chain

However, it is very difficult to determine the supplier and customer of the intangible product in the service industry. Suppliers, the service provider, customers, and the consumer have been identified in this research. This exploratory study also identifies supplied inputs, customer-consuming output (O/P), customer-supplying input (I/O) and finally supplied outputs (Habib and jungthirapanich, 2010e).

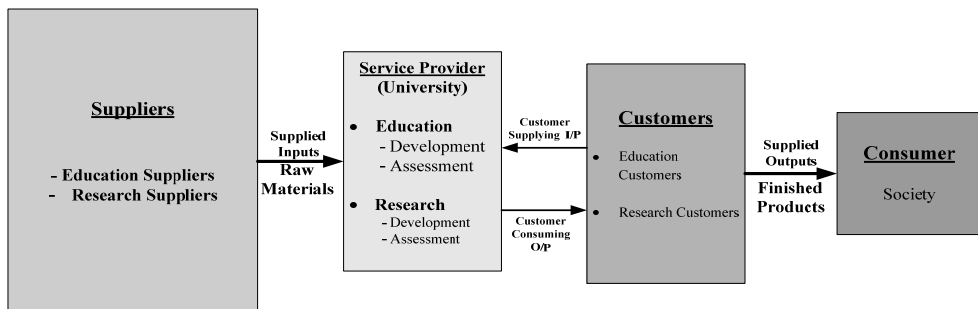


Fig. 3. Simplified form of supply chain management for the universities

Figure 4 illustrates an education supply chain and a research supply chain, which together form the integrated supply chain for the universities to produce quality outcomes. The three decision levels including strategic, planning and operating level in the university have been explored in this research model. These three decision phases build up an integrated form of educational supply chain for the universities. The performance of this supply chain depends on the quality of the graduates with desirable quality and quality research outcomes of the university.

*A. Suppliers*

In the conceptual model, the researcher identified two major parts in the suppliers, namely education suppliers and research suppliers for the universities (Habib and Jungthirapanich, 2009e; Habib, 2010b; Habib and Jungthirapanich, 2010d).

*Education Suppliers:* Suppliers of the student (High school/college), suppliers of the faculty (other universities), Self funding students, source of fund - family (parents, siblings), relatives, etc. government and private organizations (scholarship), suppliers of assets or equipment (furniture, computer, networking equipment, etc.), suppliers of educational materials (stationery, instruction materials, etc.).

*Research Suppliers:* Suppliers of internal research projects (university self funding), suppliers of external research projects (external research funds, Ministry of education, private organizations, etc.).

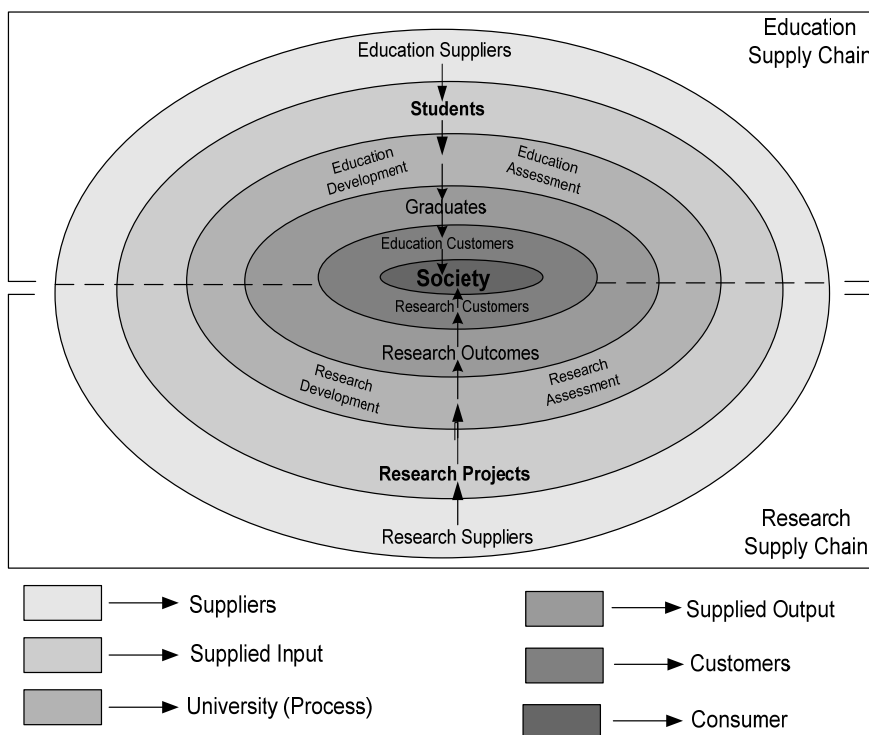


Fig. 4. An integrated supply chain for the universities

### *B. A Service Provider*

A university is regarded as a service provider in this paper. The researcher identified two major wings including development and assessment for both education and research in the university. Fig. 3 represents educational supply chain for the universities in four aspects, including programs establishment, university culture, faculty capabilities, and facilities, are considered for development and assessment in both education and research part. The final outcomes of the university, i.e. graduates and research outcomes are delivered to the society (Habib and Jungthirapanich, 2010c).

### *C. Customers*

In the conceptual model, the researcher identified two major parts in the customers namely education customers and research customers for the universities (Habib and Jungthirapanich, 2008b; Habib, 2009). Some of the graduates would be added in the service provider as the supplied input. On the other hand, some graduates would be acted as the supplied output to the end customer. Therefore, the researcher also identified graduates as the supplying input customer in this supply chain.

*Education Customers:* Graduates, family (parents, siblings, relatives, etc.), employers of government and private organizations

*Research Customers:* Funding organizations of research projects, research outcomes (researchers, research publications, findings etc.), Others (research professional organizations -IEEE, INFORMS, ACM, Society of manufacturing engineers etc. and Trade associations -American trade association, Grocery manufacturers association, etc.).

### *D. Consumer*

The researcher identifies the society as the end customer or the consumer in this educational supply chain. As universities are the part of the society, the final outcomes of this supply chain, including graduates with desirable quality and quality research outcomes are delivered to the society (Habib and Jungthirapanich, 2008a, 2009c, 2009e).

## **4.1 Final Outcomes**

### *Graduates with Desirable Quality*

Graduates with desirable quality is one of the final outcomes in the educational supply chain management. Benchmarking and value enhancement determinants are identified and incorporated in the process of the university to produce graduates with desirable quality.

(a) Graduates benchmarking includes knowledge (tacit or explicit), skills, competencies, capabilities, ethics, career development programs, etc.

(b) Graduates value enhancement includes source of fund (self-funding, scholarship, etc.), wisdom, faculty capabilities, facilities, Information & Communication Technology (ICT), research involvements, etc.

### *Quality Research Outcomes*

The author defined another final outcome of the educational supply chain management is quality research outcomes. The university develops strategic plans for multidisciplinary research to maintain an emphasis on research as an important component of the academic mission of the university. Research outcomes may include problem solution, pure theory, internal and external projects applications, thesis findings, research publications, or research findings, etc.



### 4.2 ITESCM Model

From the literature review, the researcher develops the proposed ITESCM (Integrated Tertiary Educational Supply Chain Management) model for the universities. This model depicts the integrated form of educational supply chain and educational management for the universities in the following Figure 5. Educational supply chain also consists of education supply chain and research supply chain.

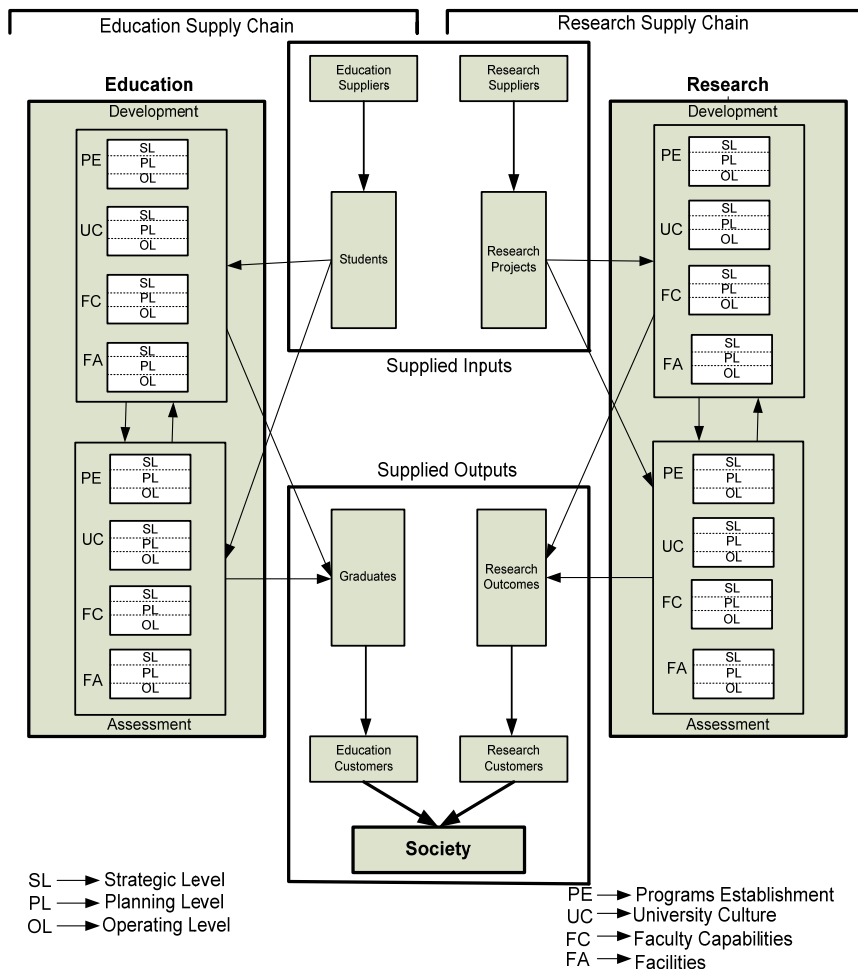


Fig. 5. Integrated Tertiary Educational Supply Chain Management (ITESCM) model for the universities

## 5. ITESCM Model Evaluation

The proposed ITESCM (Integrated Tertiary Educational Supply Chain Management) model is the integrated form of educational management and educational supply chain for the universities. There are two main contributions of the universities to the society, namely education and research. Both contributions are further categorized into development and assessment. Each category is analyzed in four different aspects, namely programs establishment, university culture, faculty capabilities, facilities at three decision levels, including strategic, planning, and operating levels. To enhance customer satisfaction, generating quality outcomes for the betterment of the end customer, i.e. the society, the author developed this research model for the universities.

### 5.1 Educational Management

In the educational management, the researcher defines education development, education assessment, research development and research assessment for the universities to provide the conclusion of research issue items. From the research results, they show the significant relationships among four aspects in educational management to produce quality graduates and quality research outcomes. The authors represent model A and B in this section. Model A stands for graduates and model B represents research outcomes. From the research model, the following hypotheses are established. Hypotheses 1 and 2 stand for graduates and hypotheses 3 and 4 for research outcomes.

H<sub>1</sub>: There is a relationship between education development and graduates.

H<sub>2</sub>: There is a relationship between education assessment and graduates.

H<sub>3</sub>: There is a relationship between research development and research outcomes.

H<sub>4</sub>: There is a relationship between research assessment and research outcomes.

#### 5.1.1 Model A: Graduates

The researcher identified graduates as final outcomes of the education part in the university. Education part is divided into two segments including education development and education assessment. Model 3 contains group 1 and group 2. Group 1 is defined as the education development in the model 3. There are four subgroups, including subgroup 1, subgroup 2, subgroup 3 and subgroup 4 those are representing programs establishment, university culture, faculty capabilities and facilities respectively.

On the other hand, group 2 stands for the education assessment in the model 3. There are 4 subgroups, namely subgroup 5, subgroup 6, subgroup 7 and subgroup 8 those are representing programs establishment, university culture, faculty capabilities and facilities respectively. Figure 6 illustrates the inter relationships among different variables to justify the hypothesis 1 and 2 by SEM through AMOS.

#### Multiple Linear Regression (MLR) Equations

$$F_{\text{Group 1}} = 0.63 f_{\text{subgroup 1}} + 0.70 f_{\text{subgroup 2}} + 0.65 f_{\text{subgroup 3}} + 0.63 f_{\text{subgroup 4}} \quad (1)$$

$$F_{\text{Group 2}} = 0.68 f_{\text{subgroup 5}} + 0.74 f_{\text{subgroup 6}} + 0.69 f_{\text{subgroup 7}} + 0.66 f_{\text{subgroup 8}} \quad (2)$$

$$F_{\text{Graduates}} = 0.97 F_{\text{Group 1}} + 0.92 F_{\text{Group 2}} \quad (3)$$

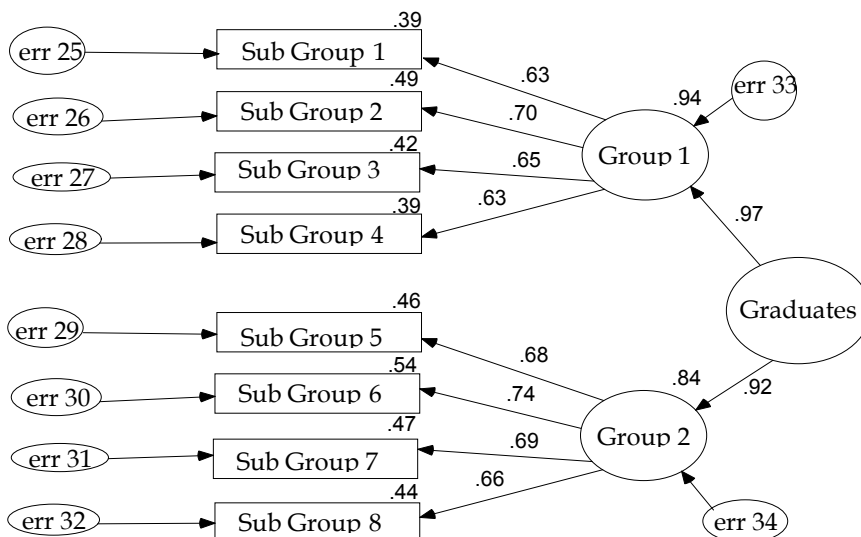


Fig. 6. AMOS Graphics Output of Model A (Standardized Estimates)

From the research findings, equation (1) states that university culture (sub group 2) is the most significant factor in education development. On the other hand, equation (2) represents that university culture (sub group 6) is highly contributed to education assessment. Finally, equation (3) depicts that education development is highly contributed to produce quality graduates in the universities. From equation (1), (2) and (3),

$$\begin{aligned}
 F_{\text{Graduates}} &= 0.97 F_{\text{Group 1}} + 0.92 F_{\text{Group 2}} \\
 &= 0.97 [0.63 f_{\text{subgroup 1}} + 0.70 f_{\text{subgroup 2}} + 0.65 f_{\text{subgroup 3}} + 0.63 f_{\text{subgroup 4}}] \\
 &\quad + 0.92 [0.68 f_{\text{subgroup 5}} + 0.74 f_{\text{subgroup 6}} + 0.69 f_{\text{subgroup 7}} + 0.66 f_{\text{subgroup 8}}] \\
 &= 0.61 f_{\text{subgroup 1}} + 0.68 f_{\text{subgroup 2}} + 0.63 f_{\text{subgroup 3}} + 0.61 f_{\text{subgroup 4}} + 0.63 f_{\text{subgroup 5}} + \\
 &\quad 0.68 f_{\text{subgroup 6}} + 0.63 f_{\text{subgroup 7}} + 0.61 f_{\text{subgroup 8}} \tag{4}
 \end{aligned}$$

The above equation shows the significant relationship among all factors namely programs establishment, university culture, faculty capabilities, and facilities in education development as well as education assessment to produce the graduates. University culture at education development and education assessment is highly contributed to produce the graduates in the universities.

#### Model Fit Index

Chi-square = 169.792, Degrees of freedom =19, Probability level = 0.000, CMIN/DF = 8.936 (Ratio of relative chi-square close to 5 indicates reasonable fit) (Wheaton and et al., 1997), RMSEA (Root Mean Square Error of Approximation) = 0.127, NFI (Normed Fit Index) = 0.880, CFI = 0.891 (NFI and CFI (Comparative Fit Index) values close to 1 indicate a very good fit) (Bentler, 1990).

The equation (3), (4), graphics output and above all statistical discussion on AMOS magnifies that hypotheses 1 and 2 fail to reject and states that there are significant relationship between education development and graduates as well as education assessment and graduates.

### 5.1.2 Model B: Research Outcomes

The author identified research outcomes as final outcomes in the research wing of the university. This part is divided into two segments including research development and research assessment. The model 6 contains two groups including group 3 and group 4. Group 3 is defined as the research development in this model. There are four subgroups, namely subgroup 9, subgroup 10, subgroup 11 and subgroup 12, those are representing programs establishment, university culture, faculty capabilities and facilities respectively. On the other hand, group 4 stands for the research assessment in this model. There are four subgroups, namely subgroup 13, subgroup 14, subgroup 15 and subgroup 16, those are representing programs establishment, university culture, faculty capabilities and facilities respectively.

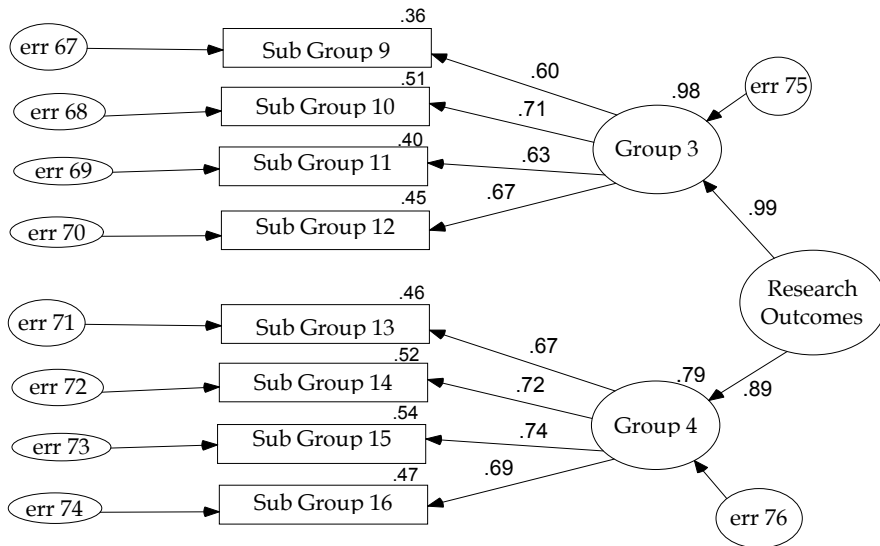


Fig. 7. AMOS Graphics Output of Model B (Standardized Estimates)

Figure 7 illustrates the inter relationships among different variables to justify the hypothesis 3 and 4 by SEM through AMOS.

#### Multiple Linear Regression (MLR) Equations

$$F_{\text{Group 3}} = 0.60 f_{\text{subgroup 9}} + 0.71 f_{\text{subgroup 10}} + 0.63 f_{\text{subgroup 11}} + 0.67 f_{\text{subgroup 12}} \quad (5)$$

$$F_{\text{Group 4}} = 0.67 f_{\text{subgroup 13}} + 0.72 f_{\text{subgroup 14}} + 0.74 f_{\text{subgroup 15}} + 0.69 f_{\text{subgroup 16}} \quad (6)$$

$$F_{\text{Research Outcomes}} = 0.99 F_{\text{Group 3}} + 0.89 F_{\text{Group 4}} \quad (7)$$

From the research findings, equation (5) states that university culture (sub group 10) is the most significant factor in research development. On the other hand, equation (6) represents that faculty capabilities (sub group 15) are highly contributed to research assessment. Finally, equation (7) depicts that research development is highly contributed to produce research outcomes in the universities.

From equation (5), (6) and (7),

$$\begin{aligned}
 F_{\text{Research Outcomes}} &= 0.99 F_{\text{Group 3}} + 0.89 F_{\text{Group 4}} \\
 &= 0.99 [0.60 f_{\text{subgroup 9}} + 0.71 f_{\text{subgroup 10}} + 0.63 f_{\text{subgroup 11}} + 0.67 f_{\text{subgroup 12}} \\
 &\quad + 0.89 [0.67 f_{\text{subgroup 13}} + 0.72 f_{\text{subgroup 14}} + 0.74 f_{\text{subgroup 15}} + 0.69 f_{\text{subgroup 16}}] \\
 &= 0.59 f_{\text{subgroup 9}} + 0.70 f_{\text{subgroup 10}} + 0.62 f_{\text{subgroup 11}} + 0.66 f_{\text{subgroup 12}} + \\
 &\quad 0.60 f_{\text{subgroup 13}} + 0.64 f_{\text{subgroup 14}} + 0.66 f_{\text{subgroup 15}} + 0.61 f_{\text{subgroup 16}} \quad (8)
 \end{aligned}$$

From the research results of equation (8), they show the significant relationships among four aspects, namely programs establishment, university culture, faculty capabilities, and facilities in research development as well as research assessment to produce the research outcomes in the universities. University culture and facilities in research development as well as faculty capabilities in research assessment are highly contributed to produce the research outcomes in the universities.

### *Model Fit Index*

Chi-square = 189.828, Degrees of freedom = 19, Probability level = 0.000, CMIN/DF = 9.991, RMSEA = 0.135, NFI = 0.872, CFI = 0.883 (NFI and CFI values close to 1 indicate a very good fit) (Bentler, 1990).

The equation (7), (8), graphics output and above all statistical discussion on AMOS rectifies that hypotheses 3 and 4 fail to reject and states that there are significant relationship between research development and research outcomes as well as research assessment and research outcomes.

## **5.2 Educational Supply Chain**

The author represents model C and D in this section. Model C stands for supplied inputs and model D represents supplied outputs. Hypotheses 5 and 6 stand for supplied inputs and hypotheses 7 to 10 for supplied outputs.

- H<sub>5</sub>: There is a relationship between education suppliers and students in the universities.
- H<sub>6</sub>: There is a relationship between research suppliers and research projects in the universities.
- H<sub>7</sub>: There is a relationship between graduates and education customers.
- H<sub>8</sub>: There is a relationship between research outcomes and research customers.
- H<sub>9</sub>: There is a relationship between education customers and the society.
- H<sub>10</sub>: There is a relationship between research customers and the society.

In the educational supply chain, the researcher defines supplied inputs to the university, supplied outputs of the universities to provide the conclusion of research issue items. From the research results, they show the significant relationships among different variables in educational supply chain to produce quality graduates and quality research outcomes for the betterment of the society.

### **5.2.1 Model C - Supplied Inputs**

In model C, there are two main inputs for the universities, namely students and research projects that have been evolved from education suppliers and research suppliers respectively. Figure 8 illustrates the inter relationships among different variables to justify the hypotheses 5 and 6 by SEM through AMOS. **MLR equations:**

$$F_{University} = 0.41 f_{ST} + 0.38 f_{RE\_PROJ} \tag{9}$$

$$= 0.41 [0.13 f_{ED\_SUPP}] + 0.38 [0.23 f_{RE\_SUPP}]$$

$$= 0.05 f_{ED\_SUPP} + 0.09 f_{RE\_SUPP} \tag{10}$$

From the research findings, university consists of students as well as research projects. The factor that highly contributed to the university is students. Refer to (10) also depicts the relation of education suppliers and research suppliers with the university. Research suppliers are the most significant factor in the university.

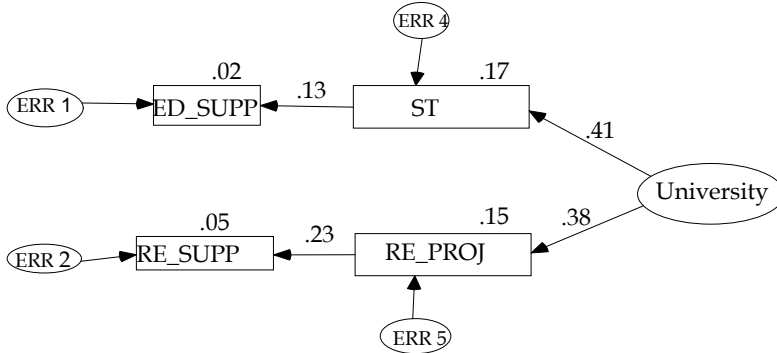


Fig. 8. AMOS graphics output of model C (standardized estimates)

**Model Fit Index:** Chi-square = 17.886, Degrees of freedom = 3, Probability level = 0.000, CMIN/DF = 5.962 (Ratio of relative chi-square close to 5 indicates reasonable fit), NCP = 14.886, FMIN = 0.036, RMSEA = 0.100, NFI = 0.720, CFI = 0.743 (NFI and CFI values close to 1 indicate a very good fit).

Equation (9), (10) graphics output and above all statistical discussion on AMOS 6 states that there are significant relationships between education suppliers and students, and research suppliers and research projects in the universities. Therefore, research hypotheses 5 and 6 fail to reject.

**5.2.2 Model D - Supplied Outputs**

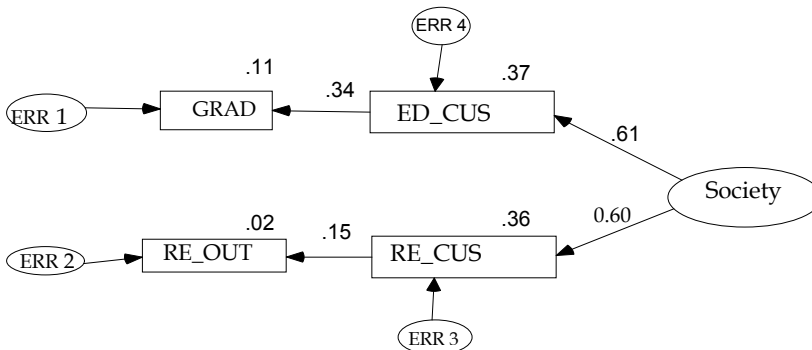


Fig. 9. AMOS graphics output of model D (standardized estimates)

In model D, the main outputs of the universities, including graduates and research outcomes will be delivered to the education customers and research customers respectively. Finally, all outcomes will be generated for the betterment of the society. Figure 9 illustrates the inter relationships among different variables to justify the hypothesis 7 to 10 by SEM through AMOS.

### MLR equations

$$F_{\text{Society}} = 0.61 f_{\text{ED\_CUS}} + 0.60 f_{\text{RE\_CUS}} \quad (11)$$

$$= 0.61 [0.34 f_{\text{Grad}}] + 0.60 [0.15 f_{\text{RE\_OUT}}] \quad (12)$$

$$= 0.21 f_{\text{Grad}} + 0.09 f_{\text{RE\_OUT}}$$

From the research finding, the society consists of graduates and research outcomes. Refer to (12) represents that graduates are highly contributed to the society. Refer to (11) also depicts that education customers and research customers are included in the society. The most significant factor in the society is education customers.

### Model Fit Index

Chi-square = 16.481, Degrees of freedom = 3, Probability level = 0.001, CMIN/DF = 5.494 (Ratio of relative chi-square close to 5 indicates reasonable fit) (Wheaton and et al., 1997), NCP = 13.481, FMIN = 0.033, RMSEA = 0.096, NFI = 0.896, CFI = 0.911 (NFI and CFI values close to 1 indicate a very good fit) (Bentler, 1990).

Equation (11), (12), graphics output and above all statistical discussion on AMOS states that there are significant relationships between graduates and education customers, research outcomes and research customers. There are also significant relationships among education customers, research customers and the society. Therefore, hypotheses 7, 8, 9 and 10 fail to reject.

From Equation (4), (8) and (12),

$$F_{\text{Society}} = 0.21 f_{\text{Grad}} + 0.09 f_{\text{RE\_OUT}}$$

$$F_{\text{Society}} = 0.21 [0.97 F_{\text{Group 1}} + 0.92 F_{\text{Group 2}}] + 0.09 [0.99 F_{\text{Group 3}} + 0.89 F_{\text{Group 4}}] \\ = 0.20 F_{\text{Group 1}} + 0.19 F_{\text{Group 2}} + 0.09 F_{\text{Group 3}} + 0.08 F_{\text{Group 4}}$$

The above equation represents the relationship between the society and education development, education assessment, research development, research assessment. Education development and then education assessment are highly contributed to the society.

### 5.3 Overall Model Fit Analysis in AMOS

Overall research model represents education supply chain, research supply chain, and educational management in terms of education development, education assessment, research development and research assessment. AMOS graphics output for overall model is illustrated in Figure 10. All are significant relationships (significant at the 0.05 level – two tailed) in the overall model.

### Model Fit Index

CFI (Comparative Fit Index) = 0.509, GFI (Goodness Fit Index) = 0.863, CMIN/DF = 8.751

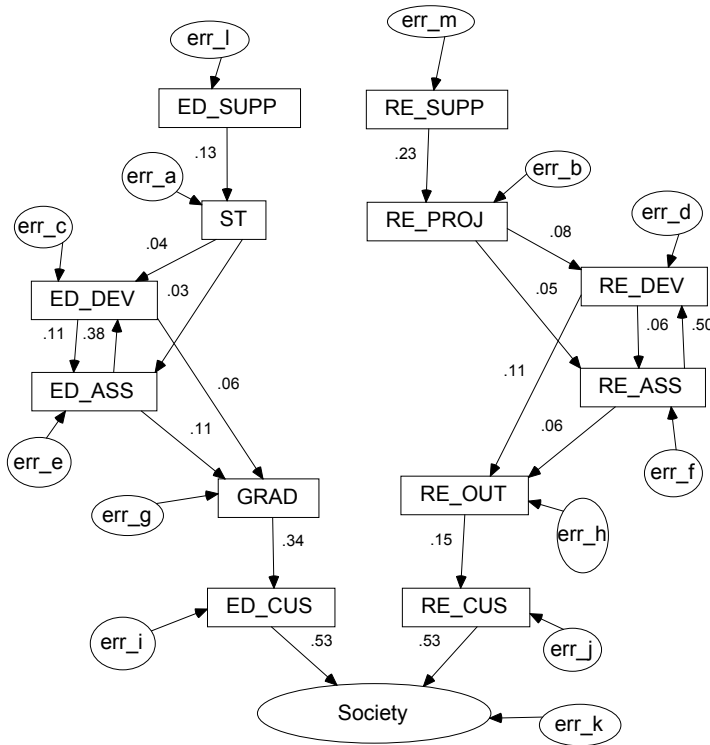


Fig. 10. AMOS Graphics Output of Overall Model (Standardized Estimates)

Modification indices should be considered only if it makes theoretical or common sense, chi-square value between 2 and 3, GFI and CFI value between 0.9 and 1 and significant relationship (Arbuckle, 2005). We can improve the overall model by using the highest Modification Indices (MI) that will make sense.

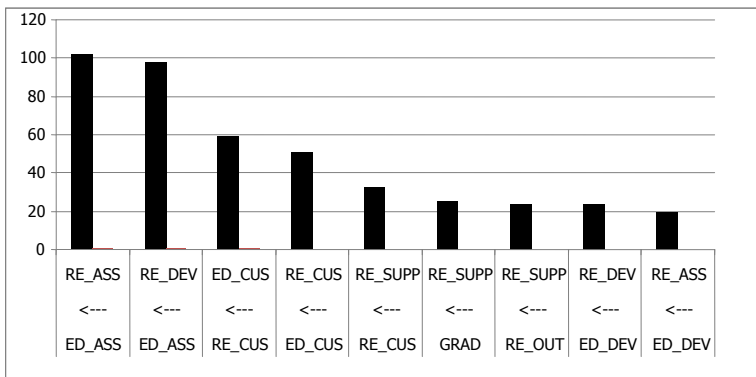


Fig. 11. Highest Modification Indices (MI) of Overall Model



### 5.3.1 Updated Model

By using AMOS highest Modification Indices (MI) of overall model in Figure 11, the researcher adds the relationship between RE\_ASS and ED\_ASS, RE\_DEV and ED\_ASS, ED\_CUS and RE\_CUS, RE\_CUS and ED\_CUS, RE\_DEV and ED\_DEV, RE\_ASS and ED\_DEV, RE\_SUPP and RE\_CUS, RE\_SUPP and RE\_OUT, RE\_SUPP and GRAD.

As there is an insignificant relationship between RE\_CUS and ED\_CUS at the level 0.05 (two-tailed), we can remove this relationship. Updated model has been illustrated in Figure 12.

*Model Fit Index:* CFI = 0.908, GFI = 0.958, CMIN/DF = 2.864

In updated model, the value of GFI and CFI is more than that of overall model. Based on CFI, GFI, CMIN/DF, updated model represents a very good fit.

The current university administrators or prospective investors could apply this updated model as actual implementation to produce quality outcomes, i.e. graduates and research outcomes, for the betterment of the society.

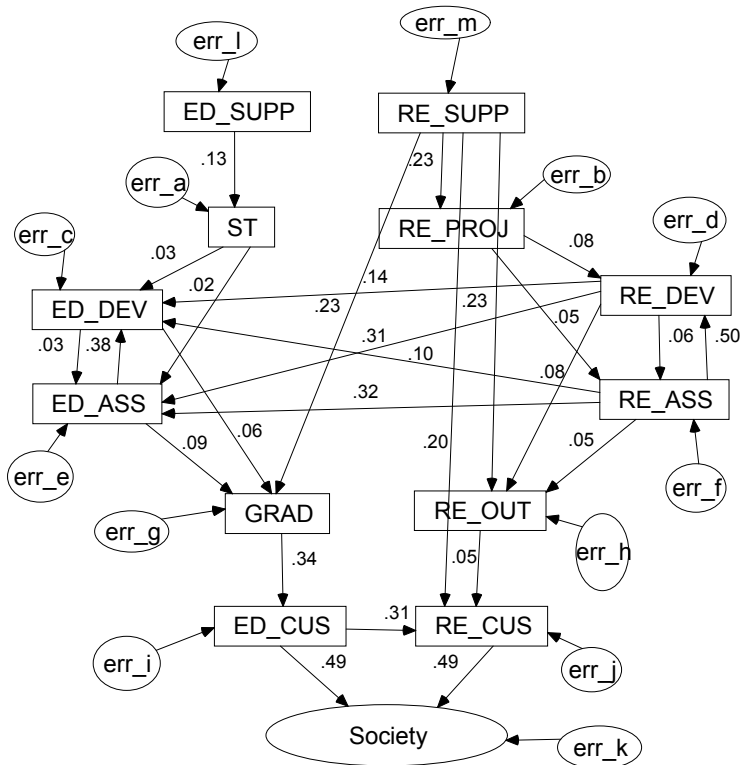


Fig. 12. AMOS Graphics Output of Updated Model (Standardized Estimates)

## 6. Discussion

### 6.1 Educational Management

In the educational management, the researcher defines education development, education assessment, research development and research assessment for the universities to provide the conclusion of research issue items. From the research results, they show the significant relationships among four aspects in educational management to produce quality graduates and quality research outcomes.

From the literature review and conceptual model, quality graduates will be produced through proper education development and proper education assessment.

$$\text{Graduates} = 0.97 \text{ ED\_DEV} + 0.92 \text{ ED\_ASS}$$

From the research results, education development is highly contributed to the graduates in the universities.

$$\begin{aligned} \text{Graduates} = & 0.61 (\text{Prog. Estab\_ED\_DEV}) + 0.68 (\text{Univ. Cult\_ED\_DEV}) + 0.63 (\text{Fac.} \\ & \text{Capab\_ED\_DEV}) + 0.61 (\text{Facilities\_ED\_DEV}) + 0.63 (\text{Prog. Estab\_ED\_ASS}) + 0.68 \\ & (\text{Univ. Cult\_ED\_ASS}) + 0.63 (\text{Fac. Capab\_ED\_ASS}) + 0.61 (\text{Facilities\_ED\_ASS}) \end{aligned}$$

From the research findings, university culture in education development and university culture in education assessment are highly contributed to the graduates in the universities.

From the literature review and conceptual model, quality research outcomes will be produced through proper research development and research assessment concurrently.

$$\text{Research Outcomes} = 0.99 \text{ RES\_DEV} + 0.89 \text{ RES\_ASS}$$

From the research results, research development is highly contributed to the research outcomes in the universities.

$$\begin{aligned} \text{Research Outcomes} = & 0.59 (\text{Prog. Estab\_RE\_DEV}) + 0.70 (\text{Univ. Cult\_RE\_DEV}) + \\ & 0.62 (\text{Fac. Capab\_RE\_DEV}) + 0.66 (\text{Facilities\_RE\_DEV}) + 0.60 (\text{Prog. Estab\_RE\_ASS}) \\ & + 0.64 (\text{Univ. Cult\_RE\_ASS}) + 0.66 (\text{Fac. Capab\_RE\_ASS}) + 0.61 (\text{Facilities\_RE\_ASS}) \end{aligned}$$

From the research findings, university culture in research development, facilities in research development and faculty capabilities in research assessment are highly contributed to the research outcomes in the universities.

### 6.2 Educational Supply Chain

In the educational supply chain, the researcher defines supplied inputs to the university, supplied outputs of the universities to provide the conclusion of research issue items. From the research results, they show the significant relationship among different factors in educational supply chain to produce quality graduates and quality research outcomes for the betterment of the society.

There are significant relationship between education suppliers and students as well as research suppliers and research projects to enhance the universities.

$$\text{University} = 0.41 \text{ ST} + 0.38 \text{ RE\_PROJ}$$
$$\text{University} = 0.05 \text{ ED\_SUPP} + 0.09 \text{ RE\_SUPP}$$

From the research findings, students and research suppliers are highly contributed to the universities.

There are significant relationship between education customers and graduates as well as research customers and research outcomes to enhance the society.

$$\text{Society} = 0.61 \text{ ED\_CUS} + 0.61 \text{ RE\_CUS}$$

This equation depicts that education customers and research customers have equal contribution to the society.

$$\text{Society} = 0.21 \text{ Grad} + 0.09 \text{ RE\_OUT}$$

From the research findings, graduates are highly contributed to the end customer, i.e. the society. From the research framework, the society consists of graduates and research outcomes.

$$\text{Society} = f(\text{Graduates, Research Outcomes})$$

The authors defined the society as the function of graduates and research outcomes; therefore, well-being society depends on the quality graduates and the quality research outcomes. The following equation states that education development and consequently, education assessment in the university are highly contributed to the society.

$$\text{Society} = 0.20 \text{ ED\_DEV} + 0.19 \text{ ED\_ASS} + 0.09 \text{ RE\_DEV} + 0.08 \text{ RE\_ASS}$$

The different aspects in the educational management affect educational supply chain to produce the quality graduates and quality research outcomes for the end customer, i.e. the society.

### 6.3 Application Guidelines

In this research, the ultimate goals of the study are the quality graduates and quality research outcomes. SEM technique was applied to define factors that affect the integrated educational supply chain management model. This research is focused on the universities and all stakeholders, including experts in university administration, faculty members, staff, employers and graduates, accomplished the survey.

- From research findings, university culture enhances education development and assessment in the universities to produce quality graduates. Therefore, university management or university council would be revised to review their performance for further improvements. In that case, good governance would be highly recommended for the universities.
- To foster good governance in the tertiary educational institutions, selection of key executives is very important. In order to develop the university as center of excellence in the society, key executives must possess some characteristics like visionary, ethical, high potentiality, high capability, etc. In fact, university culture is the prime mover for other aspects, including programs establishments, faculty capabilities, and facilities in the universities.

- From research findings, University culture in education development and assessment is highly contributed to the society. In other words, graduates are highly contributed to the society. By the good governance, university culture could produce quality graduates through proper academic development and academic quality assessment for the well-being society.
- To produce quality graduates, education assessment would evaluate the students through proper academic development. Quality assurance center would assess the quality of the graduates in terms of different performance indicators through quality assessment strategies and plans.
- From the research findings, university culture and facilities are highly contributed to the research development, and faculty capabilities enhance research assessment in the universities to produce quality research outcomes. Therefore, university management must provide all facilities, including online databases, digital libraries, journals, etc. for the research projects and engage those faculty members who have expertise in research.
- To produce quality research outcomes, research assessment would evaluate the research projects through proper research development. Therefore, universities should have strategies and plans to assess the performance of the internal and external research projects through research center.
- Faculty members' recruitment is the key factor in the universities to produce quality graduates. The office of human resource management could select the faculty members not only based on the academic performance, but also provide attention towards other capabilities like potentiality, ethical, motivation, controlling, knowledgeable, research involvements, etc.
- Different programs establishment in the universities depends on the demand of the society. In that case, universities must have provision for regular monitoring the feasibility of different new programs based on the respective country and global perspectives. Diversification in programs establishment would be fruitful for the students to build up their careers in different fields, which they like.
- University's quality assurance center would assess the quality of the graduates and research outcomes in terms of performance indicators through quality assessment strategies and plans.
- University must ensure the modern teaching facilities for the students. Libraries, classroom facilities, laboratory facilities, online facilities, international publications, etc. are mandatory for any university.
- Universities, specially teaching based universities must have reviewed their students' research involvements. Universities could arrange different international conferences in the universities through various professional organizations, which would enhance the students to involve in the research.
- Universities must set up research center to coordinate the different entities in the research supply chain. Universities research center would follow up the research developments to make sure the quality research outcomes for the research customers.
- As research involvements are one of value enhancements for the graduates, however, research suppliers have to be related with the graduates to ensure the type of the research projects that able to enhance the quality of the graduates. Different research projects of internal and external research suppliers would enlighten the quality of the graduates.
- As ethics is the identified as benchmarking for the graduates in this study, therefore, university must have Ethics Center. This center will circulate ethics seminar, ethics courses, etc. to the students as the mandatory to complete the graduation.

## 7. Conclusion

In summary, this research represents the first large scale empirical study that systematically investigate input of the university, output of the university through educational supply chain. This empirical study of 493 respondents from all stakeholders including experts and administrators of the university, employers, graduates, etc. are applied. The hypotheses testing and structural equation modeling (SEM) through AMOS are also applied.

One of the main goals of an educational supply chain is to improve the well-being of the end customer or the society. Improved Well-being society would be possible if we could able to produce quality graduates and quality research outcomes by implementing proper educational supply chain for the universities from the raw materials, i.e. students and research projects to finished products, i.e. graduates and research outcomes.

It is a surprising fact that researchers develop supply chain models mostly for improving business operations. Few, particularly academic researchers, do not realize that the research on academic supply chain management may also be conducted for their own educational institutions (Habib & Jungthirapanich, 2008a). This empirical research will fulfill that space. The applicability of the model can be confirmed empirically. However, model evaluation by actual implementation is suggested for prospective investors or current university administrators. The current decision makers who need to improve their management can apply the research equations of educational supply chain management model to their universities. This study provides educational management a new dimension to understand how supply chain management contributes to successful university operations. This model for the universities provides two main contributions to the end customer, i.e. the society, including human resource contribution and research contribution.

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# Learning 2.0: collaborative technologies reshaping learning pathways

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## 1. Introduction

The development of the Internet into the highly versatile, dynamic and democratized medium it is today has brought with it incredible transformations and opportunities in practically all fields of human activity. A new set of Internet-based technological tools, all gathered together under the roof of one broad term - Web 2.0 - are describing the increasing use of the Internet as a technology platform to enhance functionality, communication and collaboration. It encompasses the explosion of Web-delivered content, interconnectivity, new applications and social networking. The term "Web 2.0" actually describes the changing trends in the use of World Wide Web technology and web design that aim to enhance creativity, secure information sharing, collaboration and functionality of the web.

Web 2.0 applications like blogs, wikis, online social networking sites, photo- and video-sharing sites and virtual worlds have known an exponentially increasing development and popularity over the past few years. Research evidence suggests that these revolutionary online tools have not only had an impact on people's private and professional lives, but have also started to affect large organizations and institutional structures, leading them towards more collaborative and synergetic approaches. This process - intrinsically based upon the latest online technologies - is extremely interesting to observe in the educational sector, as an enhanced efficiency at this level is further on naturally disseminated in all segments and fields of activity.

Moreover, taking into account all the great advantages of using such tools in providing high quality, modern educational services and catalyzing learning processes, we believe this is an extremely interesting topic, of utmost importance for the future of education and the development of generations to come. After all, we are witnessing the dawn of a new era pertaining entirely to "digital natives" (Mason & Rennie, 2007), as today's children are using Web 2.0 technologies comfortably and efficiently and they will continue to do so ever more naturally. The reason why using these tools in educational settings is so crucial, particularly at this point in time, reveals itself from two different aspects merging together. On one hand, the younger generation will always need help from their older, wiser fellows in order to learn what they need to be successful in the complicated structures of the society they will grow up to be a part of. But, on the other hand, until these digital natives will start becoming those fellows, here we are still the representatives of those few „transition“

generations in different stages of technical ability that are bound to adapt quickly to the imminent trends and find efficient measures to support imposing multiple innovations of the educational system, that will eventually permit a functional blend between the "old" and "new" tools and patterns for learning, as well as a smooth evolution of the entire system.

Bringing together the two realms of Web 2.0 and learning, in any form or type of organization around the globe, we will address the phenomenon under discussion with the term of „Learning 2.0“, as it already appears in a few pioneering research papers. Since the concept of collaborative technologies is only a few years old itself, discussions around the topic of its fusion with the educational sector are an even bigger novelty. Therefore research on Learning 2.0 is still scarce, the only comprehensive project in this area of study, apart from some disparate articles and studies on different, very restricted aspects of Learning 2.0, being one initiated by the Institute for Prospective Technological Studies (IPTS) and the European Commission Directorate Education and Culture (DG EAC) in 2008. *“Learning 2.0 – the Impact of Web 2.0 Innovations on Education and Training in Europe”* (Redecker et al, 2009) aims at gathering concrete evidence on the take up of social computing by European education and training institutions, to understand its impact on innovations in educational practices and its potential for a more inclusive European knowledge society. At the same time, this research project also envisioned identifying challenges and bottlenecks so as to devise policy options for European decision makers, all in all proposing a very complex approach to understanding the role of collaborative technologies in European education and training institutions.

Although the final report issued at the end of this study is a very important informative tool for anyone plunging into this field, there are two disadvantages entailed. First of all, the results are biased by concentrating only on European institutions, which although was one of the major premises of the project, nevertheless cannot be ignored as a restrictive feature, and second of all our entire discussion takes place on very rapidly changing grounds, the Web 2.0 movement having suffered tremendous developments during the last couple of years. Having pointed out so far only the main limitations of this front-runner contribution in the Learning 2.0 field, we would like to mention a couple of other aspects that could be added into the same category. In our opinion, this study focuses primarily upon organizational innovation measures that need to be implemented in order to assure the efficiency of Web 2.0 tools within education and training institutions, in the detriment of other key aspects of the analyzed issue. One of these could consist into the main advantages of using Web 2.0 tools in educational contexts (such as their crucial contribution in distance education, informal learning and decoding tacit knowledge, as well as in the process of developing essential character and personality traits of future citizens of the world), which we believe it is a noticeably underdeveloped aspect in this study and also one that we will try to enrich with our research endeavours.

This is why, building upon existent research, we are proposing a more general, up-to-date and logically structured overview of the Learning 2.0 field, in which we intend to emphasize all the fundamental advantages of Learning 2.0 practices and the most severe challenges laying ahead for them. Our hopes are high that a clear outline of this phenomenon and its determining landmarks – one of the priority goals of this chapter – will foster deeper interest and further research into this very lively and current topic.

In order to reach this we will begin with a detailed exposure of the Internet’s development into what it has become nowadays, providing also a general view of the web-based tools

accountable for its nomenclature. The purpose of all this will be to sketch the basic context in which we will take a deeper look at the multiple ways of Web 2.0 applications transforming learning patterns and pathways, or more exactly at all the advantages, opportunities and challenges brought by using such technologies for learning and at the ways in which current structures must metamorphose in order to best accommodate the positive aspects, while eliminating the negative ones.

## 2. The development of the Internet into Web 2.0

We would not be able to talk about innovative collaboration technologies nowadays without having witnessed over the past few decades one of the most influential global scale phenomenon, that will have definitively reshaped the history of human kind - the rise of the Internet. According to official statistics, the growth of the World Wide Web in terms of number of users and their interconnected networks has been exponential for almost two decades.<sup>1</sup>

The reach of the Internet is global - although it began in the US and is unquestionably a western technology, its presence and growth is no longer limited to western cultures. In fact, highest growth rates are registered in other regions such as Africa, the Middle East and Latin America, all of which points out to a more and more interconnected world. And the rationale behind this continuously increased interconnectedness is nothing else but the omnipresent ambition of overcoming geographic distances as primary barriers to information and knowledge access at a global scale.

The incredible growth rate of the Internet in such a short period of time has also made it evolve into a more user-friendly medium, which allows us to define it today according to both a technical and a social model. Therefore, the major impact of its growth may not be in the connectivity itself (which is significant, as mentioned above), but in the secondary changes in behaviour and values that such connectivity seems to stimulate (Mason and Hart, 2007).

The emerging technical model means that the evolutionary development of web technology enables new capabilities for users. Higher bandwidths mean that images and videos are more readily available, thus increasing the richness of the media accessible on the web. Additionally, users can label, or "tag" pages and information units. Consequently, the web becomes increasingly dense in terms of primary content (the text web pages, the images and the video), the metadata of tags, and the linkages among sites and pages. Collectively, all three (primary content, metadata, and linkages) create a set of extraordinarily rich sources of information, so that becoming aware of the combination of the three dimensions presents opportunities for learning and for innovative connections among previously unrelated assemblages of facts and relationships (Mason and Hart, 2007).

The emerging social model is enabled by how people choose to use the evolving technical capabilities. These permit and even encourage the formation of new social networks focused on particular interests or other shared characteristics, ranging from such simple concepts as attending the same school to more complex associations such as a shared interest in particular types of books or hobbies.

The significance of these examples of Internet deployment - one oriented toward software development, one purely social - suggests that what we are seeing is a new approach to using the giant network. It has become the meeting space - a virtual "third space" for

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<sup>1</sup> <http://www.internetworldstats.com/stats.htm>

gathering, beyond the physical ones like the workplace and the home - that goes beyond simply searching for and accessing information. The Internet is changing how we interact with each other, if it's either for learning from each other, for working together or for new ways of recreation. What it does is actually gathering a wide range of intertwined advanced and emerging technologies into the so-called *second phase* of the evolution of the online world. This is also the reason why the term "Web 2.0" has become so popular for defining these new technologies of the Internet, representing - as shown above - only the suggestion of an upgraded network, of an Internet naturally developed into a new stage of existence and functionality.

According to Tim O'Reilly (2005), the one who introduced this term, Web 2.0 is the business revolution in the computer industry caused by the move to the Internet as a platform, and an attempt to understand the rules for success on that new platform. O'Reilly said that the "2.0" refers to the historical context of web businesses "coming back" after the 2001 collapse of the dot-com bubble, in addition to the distinguishing characteristics of the projects that survived the bust or thrived thereafter. The Internet era prior to that, the one pertaining to web developers and specialists only, is known as the Web 1.0 period, while Web 2.0 is what we call the democratized Internet or the Internet for everybody, since anyone in the world can easily go online and create their own contents there.

What stays behind this empowerment of the masses, of this engagement in mass participation is the fact that all the Web 2.0 technologies under the loop here make it almost effortless for individuals to contribute to the web based discussion and provide an extremely convenient support for social interaction and exchange of one form or another. Since these tools have transformed the Internet into a place for networking, community building and sharing collective experience, some have been led to describe this new phenomenon of massively distributed collective intelligence as "the wisdom of crowds" (Ballantyne & Quinn, 2006), giving a first hint towards the bigger idea developed throughout this chapter of people sharing knowledge, learning together and exploring new ways of capturing and disseminating their intelligence, all processes enabled by innovative technologies of the Internet.

To enter more concretely into the world of Web 2.0 tools and paint a fairly comprehensive picture of these technologies without making use of an excessively technical vocabulary, here are the most popular ones of these tools and what they capture in essence:

- *Weblogs* or *blogs* are freeform digital canvases used to communicate in an open setting or well-defined group to capture topic-specific content in the form of articles (posts) listed in reversed chronological order; blogs can encompass all sorts of content, from visual, audio and video, as well as links to other blogs, information about the author and readers' comments; the term *blogosphere* has been born with the explosion of blogs around the world - there are currently around 100.000 new blogs created daily (Pascu, 2008) - describing the online world of these public writing environments;
- *Wikis* are web-based tools designed for collaborative, unstructured interactions among formal and informal groups, popular with project teams for coordinating work, team editing and capturing project updates; the most well-known example of a wiki is Wikipedia, a collaboratively-created online encyclopaedia with more than 75000 active contributors working on more than 10 million articles in 250 languages (<http://wikipedia.org/>).

- *Tagging, social bookmarking and folksonomies* represent basically assigning categories/names to Web and other content, such as articles, books (Amazon), pictures (Flickr), videos (YouTube), blogs (Technorati) and wiki entries, or institutional and team documents;
- *Social networking/online communities* refer to Web-based sites or internal platforms that supports interaction among users of all kinds;
- *Social filtering* means letting users rate content to create collective opinion of its relevance and value;
- *Mash-ups* are the result of combining data from two applications (usually with open application programming interfaces) that weren't originally intended to work together.
- *Virtual worlds* are nothing else but virtual environments like Second Life or similar online 3D virtual worlds where users can socialize, connect and create using free voice and text chat.

All of these tools and others have slowly made their way into most every aspect of human life. We use them to stay connected with each other, to work more efficiently, to extend our network of peers, to enhance marketing and management activities and basically to share everything - from personal to field-specific information, from comments and opinions to institutional knowledge. Further on we are going to see how they are used also in enabling learning processes - formal or informal - what are the premises for such innovations in the realm of education and what amazing opportunities they bring along from this very specific and interesting point of view.

### 3. From Web 2.0 to Learning 2.0

Having a fairly clear image about some of the most largely used Web 2.0 tools and how the Internet developed into incorporating such innovative technologies, we can now reach the nucleus of our endeavour and address their role in learning and educative processes. We are basically referring to emerging initiatives of integrating Web 2.0 applications in educational contexts, a phenomenon unsurprisingly labelled as Learning 2.0. As it was mentioned before, there have been a lot of discussions about the effect that web technologies are having on commerce, media and business in general but a much more little coverage on the impact they are having on education. Like the web itself, technology enabled learning processes have gone through profound transformations as well. It actually all started with *e-learning*, comprising all forms of electronically supported learning and teaching, content being delivered via the Internet, intranet/extranet, audio or video tape, satellite TV, and CD-ROM, enabling the transfer of skills and knowledge.

The early promise of e-learning though - that of empowerment - has not been fully realized, as for many the experience of e-learning has been no more than a hand-out published online, coupled with a simple multiple-choice quiz, which is hardly inspiring, let alone empowering. This happened because the traditional approach to e-learning has been to employ the use of a Virtual Learning Environment (VLE), software that is often cumbersome and expensive - and which tends to be structured around courses, timetables, and testing (Becta, 2007).

This is an approach that is too often driven by the needs of the institution rather than the individual learner.

Teachers sensed this major flaw of e-learning materials and have started to explore the potential of blogs, media-sharing services and other social software - which, although not designed specifically for e-learning, can be used to empower students and create exciting new learning opportunities. And this is how, by using this new web services, e-learning has tapped into its potential of becoming far more personal, sociable and flexible - in other words, of becoming Learning 2.0. One of the pioneers that intuitively recognized the beginning of this transition is Stephen Downes<sup>2</sup>, a senior researcher with the National Research Council of Canada based in Moncton, New Brunswick at the Institute for Information Technology's e-Learning Research Group, who firstly coined the phenomenon as e-learning 2.0 and described it as an approach that combines the use of discrete but complementary tools and web services such as blogs, wikis, and other social software to support the creation of ad-hoc learning communities.

In order to better understand how this happens specifically, we are further on going to look into the use of each of the major Web 2.0 tools in part for educational purposes.

We are going to start with *blogs*, as they are very easy and flexible tools for using, with various educational advantages, as shown by the increasing number of research studies in their educational usage. Blogs not only remove the technical barriers to writing and publishing online, but the „journal“ format encourages students to keep a record of their thinking over time. Blogs of course also facilitate critical feedback, by letting readers add comments, which could be from teachers, peers or a wider audience. So it is suggested that blogs enhance writing skills, facilitate reflection, encourage critical thinking with collaborative learning, and provide feedback and active learning (Ellison & Wu, 2008). Blogs are well suited to serve as online personal journals because they enable students sharing files and resources, giving them the possibility of writing for readers beyond their classmates (Bruns, 2008). In addition, blogs can be used as e-portfolios that keep records of personal development process, reflections and achievement (Alexander, 2007). The beauty of it is that a blog needn't be limited to a single author - it can mix different kinds of voices, including fellow students, teachers and mentors, or subject specialists (experts of the discussed matter or even personalities of the world outside immediate education circles, such as authors of studied novels or creators of studied art pieces), becoming a very interactive medium for learning with all these different peers being able to bring their input on a specific curricular subject in a certain virtual space.

As blogs, *wikis* have also attracted attention in educational field for their advantages and usability, and studies about using wikis in education have increased in number. Wikis are considered to be effective tools for learning and teaching as they facilitate collaborative learning, provide collaborative writing, support project based learning, promote creativity, encourage critical searching, support inquiry based and social constructivist learning (Konieczny, 2007). Some of other educational usage of wikis are also suggested as classroom websites, easy course administration and timetabling, easy online updating content, online dictionary, student feedback and self assessment, bibliographically organized class or group projects, virtual classes for online collaboration, creating frequently asked questions (FAQ) for classroom or students (Augar et al, 2004; Konieczny, 2007).

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<sup>2</sup> <http://www.downes.ca/news/OLDaily.htm>

*Podcasting* has also become a popular technology in education, in part because it provides a way of pushing educational content to learners. For example, Stanford University has teamed up with Apple to create the Stanford iTunes University<sup>3</sup>, which provides a range of digital content (some closed and some publicly accessible) that students can subscribe to using Apple's iTunes software. Especially as podcasting is being used with mobile devices, it can be viewed as another variant of mobile learning. Although podcasting is not a synchronous activity, it provides students information that will help them feel connected to the learning community. Moreover, as with blogging, podcasting provides students with a sense of audience - and they are highly motivated to podcast because the skills required seem relevant to today's world (Lee et al, 2008).

*Social networks* can also be viewed as pedagogical tools that stem from their affordances of information discovery and sharing, attracting and supporting networks of people and facilitating connections between them, engaging users in informal learning and creative, expressive forms of behaviour and identity seeking.

Even *media sharing* sites like Flickr or YouTube have found their use within education. Flickr provides a valuable resource for students and educators looking for images for use in presentations, learning materials or coursework, and the tagging of images makes it much easier to find relevant content. Just as well, YouTube can be used in several interactive assignments where the final result can be viewed/appreciated/commented on in video format online by classmates and the wider YouTube community.

So far we have managed to get only a brief glance into the use of Web 2.0 tool for education and learning, the topic being enriched with new practical examples or best practices every day. At the same pace increase also the research efforts of studying the impact of each and every one of these new media in educational contexts, which is a gratifying thing, bringing us more and more evidence of Web 2.0 technologies clearly reshaping learning pathways at the moment. To quickly summarise all of the above, being slowly introduced also in the educational system, such applications:

- facilitate access to information for everyone, making institutional processes more transparent and the distribution of educational material more efficient;
- integrate learning into a wider community, reaching out to virtually meet people from other age-groups and socio-cultural backgrounds, linking to experts, researchers or practitioners in a certain field of study and thus opening up alternative channels for gaining knowledge and enhancing skills;
- support the exchange of knowledge and material and facilitate community building and collaboration among learners and teachers;
- increase academic achievement with the help of motivating, personalised and engaging learning tools and environments;
- implement pedagogical strategies intended to support, facilitate, enhance and improve learning processes (Redecker et al, 2009).

Thus, such emerging technologies and changing pedagogies bring out the necessity for more effective two way communication, promoting interaction and collaborative working,

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<sup>3</sup> <http://itunes.stanford.edu/>

sharing and flexible participation between all participants in the education and learning environment. We can honestly say now that we understand the Learning 2.0 phenomenon as one of utmost importance and actuality, announcing what might become a crucial impact on the future of educational pathways worldwide. Bearing this acknowledgement in mind, we will further embark on an attempt to better grasping the implications of Learning 2.0 developments, by underlining the core positive aspects they bring in, as well as the biggest challenges and bottlenecks.

## **4. Discussing Learning 2.0**

### **4.1 Opportunities and advantages**

The most obvious advantage of using Web 2.0 tools within educational and training contexts of all kind would be their contribution in terms of fostering worldwide innovation and modernization of this field. As the already undertaken research suggests and as the figure below very clearly depicts, Learning 2.0 strategies would contribute in particular to three dimensions of innovation – technological, pedagogical and organizational innovation.

The self-explanatory matrix in Figure 1 pictures the way in which Learning 2.0 strategies bring together several core aspects of our lives, providing the technological premises (new ways, tools and methods) for learning, then drawing the attention upon the basic need of organizational transformations (re-creating teaching and learning practice), so that in the end all the preconditions are there for pedagogical innovation and empowerment of the learner.

Establishing this incremental pace, Learning 2.0 strategies first of all imply the existence and usability of collaborative technologies, that would increase the accessibility and availability of learning content and would of course provide new, more efficient frameworks for knowledge acquisition, dissemination and management. Building on our introductory arguments, Web 2.0 tools allow embedding learning activities in more engaging multimedia environments, with a high degree of quality and interoperability, where dynamic or individualised learning resources are easily created. Moreover, the simple fact that Learning 2.0 helps overcoming the limitations of face-to-face instruction through versatile tools for knowledge exchange and collaboration is a great achievement per se and something that could be made the most of in remote areas where there is an unbalanced ratio between the number of learners and available teachers.

Moving forward to the next innovation dimension, namely the organizational innovation, Learning 2.0 both requires and promotes this type of transformations and it can contribute to making educational organisations more dynamic, flexible and open. Through collaborative technologies institutions in this sector can become reflective organisations that critically evaluate and revise their corporate strategies in order to support innovative pedagogies. But in order for this to happen first of all the necessary infrastructure in which social media tools are accessible to all learners and teachers needs to be provided. In addition to this, educational institutions need to make efforts towards creating an atmosphere of support for Learning 2.0, in which new teaching and learning models are fostered and new assessment and grading strategies are integrated.



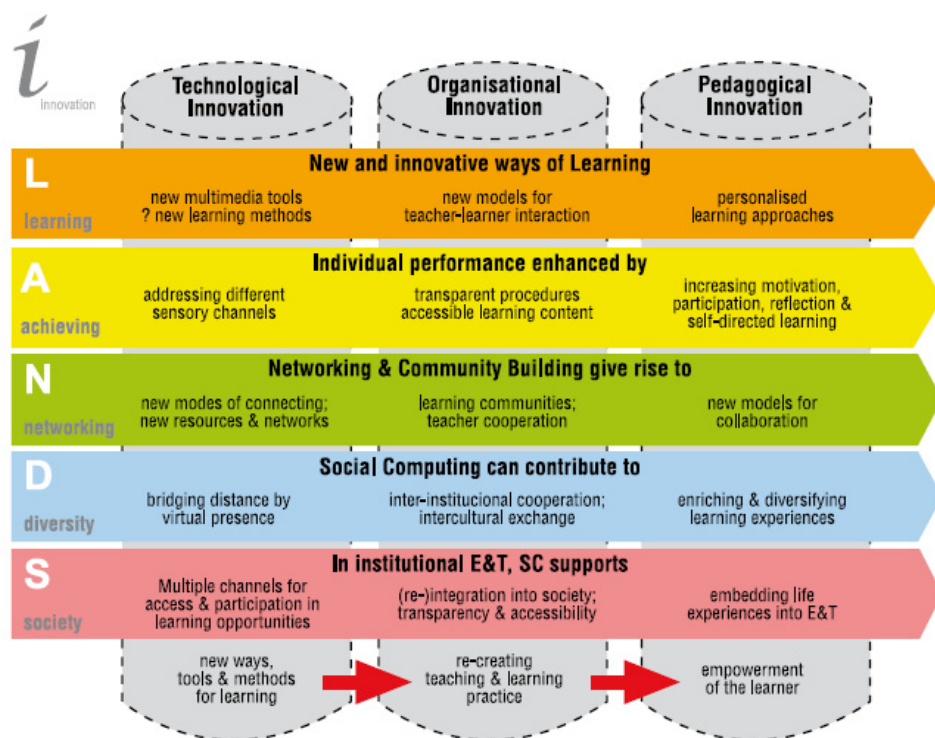


Fig. 1. The innovative potential of Learning 2.0<sup>4</sup>

Once all these developments are mobilized, the primary sine-qua-non conditions are set for learning approaches using social media to promote pedagogical innovation, which basically presumes encouraging teaching and learning processes that are based on personalisation and collaboration. The main consequence of pedagogical innovation lays in a redefining shift within interaction patterns between and among students and teachers. This way teachers become much more than just instructors or lecturers – they embrace their roles as coordinators, moderators, mediators and mentors. At the same time students' roles evolve as well, from taking responsibility for their own learning progress to also having to support each other in their learning endeavours, and jointly creating the learning content and context. Hence, Learning 2.0 offers the entire playfield where learners can and are encouraged to assume a pro-active role in the learning process and develop their own – individual and collective – rules and strategies for learning.

Much more than just enhancing innovation at these three interrelated levels, social media support engages playful approaches, provides new formats for creative expression and encourages learners and teachers to experiment with different, innovative ways of articulating their thoughts and ideas. The Learning 2.0 landscape itself is shaped by experimentation, collaboration and empowerment, and allows learners and teachers to discover new ways of

<sup>4</sup> Source: Redecker et al (2009), page 45

actively and creatively developing their individual competences, which in turn provides a rich soil where further innovation and quality learning can flourish.

Taking all this into consideration and the general fact demonstrated so far that emerging technology plays a key role especially for promoting interaction, delivering education and providing communication between individuals, we turn now to the crucial role of Learning 2.0 strategies in distance education. Several studies underlined the significance of interaction and the actual necessity of several interaction forms like student-teacher, student-student, student-content etc., contributing to the feeling of quality learning in distance education in particular. Many research studies reveal technology perceived as an enabler and intensifier of interaction, which leads at its turn to satisfaction of students, eliminating isolation feeling and effective learning outcomes (Chang et al., 2008; Cramer et al., 2007). Usluel & Mazman (2009) explained that distance learning systems use technology to separate learner from the teacher and learning group while maintaining the integrity of education process and attempting to replace the interpersonal communication and the inter subjectivity which is the essence of education transaction between teachers and learners, by a personal form of communication mediated by technology. Interaction in distance education is not limited to audio and video, or solely to teacher-student interactions, it must also represent the connectivity, the students' feel with the distance teacher, aides, peers etc., otherwise without interaction students become autonomous, isolated and procrastinate and drop out (Usluel & Mazman, 2009).

Therefore we can observe emerging technologies bringing out the necessity for more effective two way communication, promoting interaction and collaborative working, sharing and flexible participation, and also supporting the transition towards a distance learning system dominated by all these positive aspects. Moreover, emerging technologies not only have an impact on new ways of learning in distance education, but also on new models of teaching (Rennie & Mason, 2004). It is suggested that by the interactive technologies and medias which are provided by Web 2.0, these new pedagogic approaches that imply a closer relationship with students through active participation and effective two-ways communication on virtual open platforms such as blogs or wikis are also supported.

Considering distance education in very broad terms, everything we brought into discussion above is actually an only natural development in the field of education in general, following similar systematic developments in other domains as well. If we think about the many ways in which all sorts of human activities between peers situated in geographically dispersed locations have been enabled by new technologies of the Internet, we can definitely say it was only a matter of time before these technologies began to be widely utilised in long distance education. Web 2.0 tools improve the quality of the pedagogical act in such contexts, supporting it in interactive and multivalent environments, and offering a wide palette of applications to display learning content and materials, projects and assignments, group-work and examinations, which will all enrich the experience of learners engaged in long distance education by making the entire process more lively, dynamic and engaging. Beyond this, Web 2.0 technologies offer the learner itself a vast array of supports for expression and exercise of the learned content, which highly upgrade its level of preparation before examinations. If before such tools were introduced long distance students were usually "served" course materials on a certain static online location where they would access it, accumulate it and then deliver it within organized examination sessions, things are totally different now, with the new media hosting all sorts of applications whose role is to make the course materials more accessible and to help students better understand the

practical utilization of what they are learning, while also serving as support for various types of projects and assignments.

But this type of increased interaction and versatility that emerging technologies are praised for bringing into the field of distance education are also the reason why Web 2.0's advantages should be considered on a much larger scale. Around the world people engage in learning activities that are not necessarily structured or organized in any way, but appear as a natural flow of continuously modulated information, made available on the web by millions and millions of peers following their passions, interests, fears, uncertainties, etc. and tapping into the "wisdom of crowds" they end up enriching themselves. What we are basically referring to is the concept of informal learning, involving all that is learned throughout life in the day-to-day processes at home, work and leisure; and since Web 2.0 applications have slowly found their place into all of these settings it seems only obvious to reflect upon their role in informal learning activities, of whose importance is largely underestimated, but who contribute to our pool of reliable facts and experiences much more than we even imagine. The acceptance of informal learning acknowledges that there is more to learning than the absorption of "explicit" knowledge codified in texts and delivered during formal courses. It also, crucially, consists of access to "tacit" or implicit knowledge, which is exactly what all sorts of social media have best to offer. Therefore, when considering the main benefits of user-generated-content fuelling the brought up "wisdom of crowds" phenomenon, one of the most obvious one would be the fact that users have a lot of tools at their disposal to join the global conversation and actively engage in the construction of their (learning) experience, rather than merely absorb content passively. And this content will be constantly refreshed by the users, it will not require expensive expert input, something which accentuates both its purely authentic character and its reliability, the democratic nature of the web making sure that every piece of information, data or statement out there can be reinforced or refuted by users with similar experiences/authorized opinions and various ways of expression at their disposal.

All in all, through the broad variety of versatile tools, social media or Web 2.0 in general allows the implementation of more effective learning strategies that can furthermore improve individual performance, actively foster the development of transversal competences, and nurture abilities to flexibly develop skills in a lifelong learning continuum. This is easily attainable because the Learning 2.0 spectrum offers accessible, flexible and dynamic learning environments that can complement and supplement initial training. Furthermore, the networking potential of social media, together with its power to overcome time and space barriers, supports interaction and collaboration among and between learners and teachers who are geographically dispersed and enables students to broaden their horizons, and collaborate across borders, language barriers, and institutional walls. Hence, team-work abilities are highly developed by collaborative work environments supported by most of the Web 2.0 tools like shared community spaces and inter-group communication platforms, which are also a massive part of what excites young people and therefore should contribute to users' persistence and motivation to learn.

Last but not least, research results indicate that social media approaches to learning can mitigate existing inequalities and can be employed to successfully re-engage individuals who are at risk of exclusion from the knowledge society. Learning 2.0 strategies can thus effectively increase the accessibility and availability of learning opportunities for the hard to reach, and can significantly improve motivation and engagement in learning.

## 4.2 Challenges and bottlenecks

While the potential of social media for enhancing learning opportunities is substantial, there are nevertheless a few obstacles to the smooth implementation of Learning 2.0 strategies. The first one we need to mention is the very basic premise for collaborative technologies becoming a part of any process: Internet access. Although the number of people going online has increased tremendously during the past few years, the Internet is still not a commodity everywhere, in some parts of the world being actually very far from that. So then we ask ourselves how can we talk about the blessings of Learning 2.0 in a democratic way when access to such practices is prohibited sometimes due to disparities in economic and technical development.

Apart from the still non-unanimous use of Internet nowadays that will hopefully soon be overcome, we can identify further technical, organizational and pedagogical bottlenecks that hinder the fast spread and efficacy of Learning 2.0 practices. More than the lack of proper facilities allowing access to internet communication technologies in all educational institutions, access to basic digital skills constitute a major obstacle for the use of social media in education activities, and a key problem for inclusion and equality. In this sense both learners and teachers face a challenge – teachers in particular as they do not feel confident enough with their information and communication technology skills to experiment with Learning 2.0 strategies and further on they also need assistance sometimes, when their students don't have advanced digital competences, in supplying them with the necessary digital skills to safely use social media environments. Especially in this case, the mainstream deployment of Learning 2.0 approaches and strategies might be hindered by a lack of didactic methodologies, toolsets and training programmes for teachers which would also enable them to assume their new role as guides and mentors.

Another very important aspect when considering social media in educational institutions is the safety and privacy concern. Learning 2.0 strategies require the confident and critical use of these tools and an informed and critical attitude towards interactive media and digital information (Hulme, 2009). Constantly bearing this in mind is an extra responsibility that needs to be assumed by educators, who have to make sure that the identities of their learners are protected; that rules of conduct are implemented and adhered to; and that intellectual property rights are respected.

Learning 2.0 brings requirements also on institutional change, as with their rooting in formal education processes comes also a re-evaluation of educational institutions' role in society as knowledge providers. This challenges rigid existing power structures, as resistance to change limits the development of new concrete ways to support teachers, learner and administrators and generally encumber these institutions when it comes to taking an active role in deploying promising Learning 2.0 strategies. And in order to offer a very objective depiction of this situation, it is sadly accentuated by the tumultuous character of social media landscape, which underlies continuous change and transformation and hence a lot of uncertainty concerning the future development and availability of current applications and services, the reliability of user-produced content, suitable assessment and certification strategies; and valid pedagogical concepts and methods for learning with social media.

Strongly related to this aspect appears the fact that, although it is easy to see the Web 2.0 environment as an extension or development of pre-existing tools and approaches for learning, there are however some critics of these tools and user-generated content in general

that refer to a break-down in the traditional place of expertise, authority and scholarly input. They express concerns about trust, reliability and believability in relation to the move away from the printed word to the more ephemeral digital word. Furthermore, if content is created by users on different systems like podcasts, blogs, wikis, chat systems, and other social networking software, then it can be difficult to keep track of where everything is, and to access it with ease, both for those that use that content in formally structured learning frameworks and the casual visitor in search for informal learning fruits. This in turn calls for new tools to help users search and integrate across content that may be quite fragmented, a concern which is slowly but surely addressed through the proliferation of other innovative tools such as tagging, folksonomies and others.

Last but not least, we must not forget that the great uses of Web 2.0 tools for learning are not guaranteed without the users' interest in such technologies and what they have to offer. And although there is a general consensus that at least the new generation of learners are all about collaborative technologies and social media, their attention and dedication to these tools might not always be constant. This can have serious consequences on the success of Web 2.0 applications, which is strongly dependent upon the users being regularly connected and contributing to the shared content on these platforms. Thus, there is a real need to understand the dynamics of the attention-grabbing effect of Web 2.0 and harness it for education purposes.

## 5. Conclusion

There is no doubt that new information and communication technologies become a more and more important part of our lives as we speak, reaching up to every layer of our existence. With the continuous globalization of information, learning independent from time, place, cost and other needs begins to make use of innovative Web 2.0 technologies, spreading an air of freshness and imminent transformations among old systems and learning patterns and determining a reassessment of their constitutive structures in order to better accommodate envisioned advantages of the new media.

This chapter focused on the influence of such tools in the educational field as an emerging worldwide trend, endeavouring an objective depiction of pros and cons when considering the integration of social media within current conservative teaching and learning patterns. Departing from a historical approach upon the development of the internet into the so-called Web 2.0 social networking environment it has become nowadays, we are relating these innovative tools to educational practices and styles, trying to understand the emerging phenomenon of Learning 2.0 with the opportunities and challenges it brings for learner and education systems and structures worldwide.

Social media applications provide easy, fast and efficient ways to access a great diversity of information and situated knowledge. To quote Tiwana (2002), "knowledge is one of the few resources that demonstrates increasing returns to scale: the more you share it, the more it grows". Then it is only logical, if knowledge dissemination lays at the core of its thriving, that we should do everything standing in our power to stimulate and support the transfer of knowledge among as many individuals as possible even from our instruction years, offering ourselves the perfect tool for effectively building competences in collaboration with other learners, practitioners and stakeholders in a lifelong continuum. The technological development has brought us as far as being constant parts of an online, digital, parallel

universe, with new, improved and easy to use applications, making the Internet maybe the most democratic space of all and the entire mankind a co-generating part of it. So why not use this "universe" to stimulate and support core learning processes, why not tap into all the advantages and opportunities Web 2.0 tools bring in the education field, why not let them facilitate for all of us the development of key competences for the 21st century?

Learning 2.0 encompasses after all the modern tools needed for appealing to a whole new generation of learners - the "digital natives" who absorb information quickly, in images and video as well as text, from multiple sources simultaneously, they operate at very fast speed, expecting instant responses and feedback, they prefer random "on-demand" access to media, expect to be in constant communication with their friends (who may be next door or around the world), and they are as likely to create their own media (or download someone else's) as to purchase a book or a CD (Tapscott, 2009). Using Web 2.0 applications in educational processes involving this new generation of learners is speaking their own language when preparing them for life and therefore becoming more efficient at it.

As we have shown throughout this chapter, Learning 2.0 represents also the development of e-learning applications, which begin to look much more like a blogging tool (viewed as a node in a web of content, connected to other nodes and content creation services used by other students), a personal learning center (where content is reused and remixed according to the student's own needs and interests) or like a personal portfolio tool. The idea here is that students will have their own personal place to create and showcase their own work. The portfolio can provide an opportunity to demonstrate one's ability to collect, organize, interpret and reflect on documents and sources of information. It is also a tool for continuing professional development, encouraging individuals to take responsibility for and demonstrate the results of their own learning. All of these new tools and opportunities for learning and developing young people have today constitute much more than a system of education - they shape an entire environment for flourishing learning. We say this because, in comparison to the very rigid demarcations of the classical education system before the smooth adoption of Web 2.0 tools, this new environment recognizes that the learning comes not from the design of learning content but from how it is used.

Slowly and surely more and more people among which learners, trainers, pedagogs and members of the academia begin to acknowledge these facts and dedicate research resources towards the better understanding of these intrinsic transformations in the education field, of their premises, consequences and influencing factors in order to harness the potential of Learning 2.0. In this sense, a great amount of work is being done, for example, in educational gaming and simulations. Although a rather new practice, several universities around the world have already a few years experience with such Web 2.0 enabled educational simulation programs, convinced by their promise to foster interaction and team-work abilities, increase active participation, assuming responsibility and gaining experience in a professional simulated environment, as well as the opportunity to develop distance education and inter-institutional projects. Being actively involved in the development and derulation of a business simulation research project with participants from several Romanian universities, a personal appreciation of these type of programs would go directly to saying that the most important learning skills one sees children getting from such games and simulations are those that support the empowering sense of taking charge of their own learning. And the learner taking charge of learning is antithetical to the dominant ideology of a curriculum design, which is more than enough to understand why these developments are tremendously important in the field of education and why more and more

efforts should be dedicated towards a more recurrent and efficient implementation of innovative tools of all kinds in various educational contexts. One of such contexts would be also the realm of mobile learning, a rapidly rising domain, that offers not only new opportunities to create but also to connect, by defining new relationships and behaviours among learners, information, personal computing devices and the world at large (Wagner, 2005).

To sum up, the already undertaken research points out that there is not only a great potential of innovation at a technical, organizational and pedagogical level brought in by Learning 2.0 strategies, but that there are also several obstacles rising up in front of the social media efficacy in education institutions. There are indeed great arguments in favour of their adoption, like the fact that they allow learners to access a vast variety of (often freely available) learning content, which supports incessant learning and professional development even in informal settings, it enables distance education accentuating the interaction and motivation for learning, it contributes to equity and inclusion and puts pressure on education institutions to improve the quality and availability of their learning material. Moreover, since social media allow users to create digital content themselves and publish it online, it gives rise to a huge resource of user-generated content from which learners and teachers can mutually benefit, also encouraging more active and pro-active approaches to learning. Last but not least, it connects learners with one another, experts and teachers alike, allowing them to tap into the tacit knowledge of their peers and have access to highly specific and targeted knowledge in a given field of interest, at the same time supporting also the collaboration between them on a given project or a joint topic of interest, pooling resources, creating synergies and gathering the expertise and potential of a group of people committed to a common objective.

Although all these are great advantages picturing a bright future of the education system under the upcoming years of technical modernity we must not be naive and think that all these things can happen without a strong technological basis in form of access to proper facilities and advanced IT and social media instruction and assistance for learners and teachers; at the same, none of this is possible in the absence of institutional innovation and a fresh mindset that embraces the integration of social media with conservative learning techniques. Therefore we highly encourage the full acknowledgement of these impediments and further research into covering the gap of misperceptions and uncertainties regarding Learning 2.0 strategies and being concretely able to transform all of their opportunities and advantages into strong-stating facts.

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# Nonfunctional requirements validation using nash equilibria

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## 1. Introduction

The *Network security* aims to protect the network and the network-accessible resources from unauthorized access. However, the dynamic characteristics of contemporary networks combined with their increased size makes the vision of absolute network security almost impossible. Specifically, networks are vulnerable to infection by different types of electronic attacks such as viruses, Trojan horses or eavesdroppers that exploits the loopholes in the security mechanisms of networks [FAGY00]. Guaranteeing an acceptable level of security for a prospective system represents a common problem in systems engineering. Network security, is defined as a *Non-Functional Requirement* (NFR) that is influenced by functional aspects of the system such as the specification of antivirus and firewall mechanism employed on the network. This area of research has gained considerable popularity due to the implications it has on users' satisfaction, business reputation and performance. Therefore, being able to quantify the security level of a future network early in the design phase is of vital importance to its sustainability. The need to validate security requirements early has been addressed also by Lamsweerde [CILN02] and Crook [L04].

Unlike functional requirements, which can be deterministically validated, NFRs are soft variables that cannot be implemented directly; instead, they are satisfied by a combination of functional requirements. NFRs define the overall qualities or attributes of the resulting system and as such place restrictions on the software product being developed. Examples of NFR include safety, security, usability, reliability and performance requirements. Typical approaches to validating NFRs include, formal methods, prototypes, system simulations [AG05] and use of scenarios.

Model-checking techniques have been used extensively to verify and validate requirements. However, when it comes to NFR model checking is not adequate. Scenario-based requirements analysis methods, pioneered by Potts [P99], Potts and Anton [P98], and Potts et al [P94], proposed that obstacles or difficulties which might prevent a goal being achieved should challenge requirements and, hence, promote refinement of the requirements specification to deal with such obstacles. This approach was developed by van Lamsweerde [L01] and van Lamsweerde and Letier [L00], who applied formal reasoning to requirements

specifications to infer whether goals could or could not be achieved given constraints imposed by obstacles. Hierarchical goal decomposition produced specifications of the states to be achieved and the system behavior required to reach those states, so considerable problem refinement was necessary before automated reasoning could be applied. These approaches also assumed that a limited number of scenarios and their inherent obstacles are tested. This raises the question of test data coverage, i.e., just what is a sufficient set of scenarios to enable validation to be completed with confidence? While we believe there is no quick answer to this vexing problem, one approach is to reduce the set of scenarios that needs to be tested to achieve adequate validation.

This chapter addresses the aforementioned problem of generating large numbers of test scenarios during a typical scenario-based requirements validation process through Game Theory. Specifically, we reduce the complexity of the solution space to a manageable set by focusing only on combinations of strategies that satisfy the both defenders and attackers of a network. In this work, we apply game theory to assess the security NFR of a prospective network prior to its implementation and as such provide a validation of the security NFR. The assessed security NFR represents the minimum level of security guarantee for a prospective network, given a number of immunity requirements to be implemented in the network. These requirements correspond to antivirus software and their location on the network. Specifically, in the problem scenario we address in this chapter we assume that a number of harmful entities or *attackers* (or an upper bound of this number) may hit anywhere in the network. Attacks target nodes of the network. When, there is no information on how the attackers are placed on the network nodes, one may assume that they follow a *uniform distribution*. The immunity functional requirements of the network describe its defence mechanisms and are expressed by a set of *defenders*; software security systems that should guarantee an acceptable level of security to a part of the network (a link, a path, or a subnetwork). Attackers damage targeted nodes unless these are guarded by a defence software. Lamsweerde in [L04] also refers to the need to analyze the rational of the attacker in an attempt to become proactive rather than reactive in network security management. Lamsweerde refers to anti goals and anti requirements that define the attacker's strategies based on which the network designers specified functional requirements to tackle these.

### 1.1 Network Security NFR

Network Security is considered an important non-functional requirement needed to be guaranteed in a prospective computer network. Thus, it should be validated early in the design phase. Maintaining acceptable level of security in a network is analogous to preventing attacks on a country by deploying appropriate defences. Network security NFR corresponds to the ability of a network to successfully prevent attackers from maliciously exploiting its' information technology resources. With adequate security, attacks could be stopped at their entry points before they spread into the network. This requirement however, is impossible to achieve most of the times, due to the level of complexity, size and dynamic nature of contemporary computer networks. As a result designers seek to identify the best network configuration given the desire security level to be achieved using different configurations of immunity requirements.

Recent work by [KO04, ACY05] and [MPPS05b, MPPS05c], initiated the introduction of strategic games on graphs (and the study of their associated Nash equilibria) as a means of studying security problems in networks with selfish entities. By selfish we mean that each entity in the game aims to maximize its utility. In the security games studied in [KO04], a large number of players must make individual decisions related to security. The ultimate safety of each player may depend in a complex way on the actions of the entire population. [MPPS05b, MPPS05c] considers a security problem on a distributed network modeled as a multi-player non-cooperative game with *attackers* (e.g., viruses) and a *defender* (e.g., a security software) entities. More specifically, there are two classes of confronting randomized players on a graph:  $\alpha$  *attackers*, each choosing vertices and wishing to minimize the probability of being caught, and a single *defender*, who chooses edges and gains the expected number of attackers it kills. A subsequent work [MMPPS06] introduced the *Price of Defense* in order to evaluate the loss in the provided security guarantees due to the selfish nature of attacks and defenses. This notion can be also seen as a (negative) measurement of the network security. A collection of polynomial computable Nash equilibria with guarantee defense ratio (i.e. security level) is presented.

## 1.2 Road Map

The paper is organised as follows. Firstly, we illustrate the principles of game theory, followed with a description of the approach. The important question that arises here is the following: " Given the limited capabilities of the system security software, which part of the network should it choose to clean or protect from possible attack, so that the security level achieved is at least equal to the required level specified by the network designer?"

## 2. Game Theory

Game Theory is a branch of applied mathematics that attempts to analytically model the rational behavior of intelligent agents in strategic situations, in which an individual's success depends on the decisions of others. While initially developed to analyze competitions in which one individual does better at another's expense, it evolved into techniques for modeling a wide class of interactions, characterized by multiple criteria.

Most of the existing and foreseen complex networks, such as the Internet, are operated and built by thousands of large and small entities (autonomous *agents*), which collaborate to process and deliver end-to-end flows originating from and terminating at any of them. Recently, Game Theory has been proven to be a powerful modeling tool to describe such *selfish*, rational and at the same time, decentralized interactions [C01, O94]. In particular, Game Theory was successfully utilized for analyzing and most importantly *evaluating* the performance of *existing* networks in various aspects. Examples of such performance aspects include makespan, throughput, latency, resource utilization, users' satisfaction as well as security guarantees [R05, R02, ACY05, ADTW03, KP99, T04]. At the same time, a significant branch of Game Theory, *Mechanism Design* [NR99] is used to design future networks given a number of functional requirements specifications.

Game Theory has been used to understand selfish rational behaviour of complex networks, e.g. the Internet, of many "agents" (consisting the *players* of the game). In such domains,

Game Theory models players with potentially different goals (*utility functions* or *payoffs*), that participate under a common setting with well prescribed interactions (*strategies*), e.g. TCP/IP protocols. More importantly, it helps finding the *best strategy* of each player that will guarantee the best result. The core concept of Game Theory is the notion of *equilibrium* that is defined as the condition of a system in which competing influences are balanced.

## 2.1 Fundamental Components of Game Theory

The fundamental component of game theory is the notion of a *game*, expressed in normal form as  $G=(M, A, \{u_i\})$ , where  $G$  is a particular game,  $M$  is a finite set of players (decision makers)  $\{1,2,\dots,m\}$ ,  $A_i$  is the set of actions available to player  $i$ ,  $A = A_1 \times A_2 \times \dots \times A_m$  is the action space, and  $\{u_i\} = \{u_1, u_2, u_i, u_m\}$  is the set of objective functions that the players wish to maximize. For every player  $i$ , the objective function,  $u_i$ , is a function of the particular action chosen by player  $i$ ,  $a_i$ , and the particular actions chosen by all of the other players in the game,  $a_{-i}$ .

A *profile* or strategy of a game  $\sigma$  is defined as the a setting of its players in term of possible actions or the probability distribution on a set of actions for each player of the game in setting  $\sigma$ . The action of player  $i \in M$  is denoted by  $\sigma_i$ , where  $\sigma_i \in A_i$ .

The core concept of Game Theory is the notion of equilibrium that is defined as the condition of a system in which competing influences are balanced, i.e. steady-state conditions. More informally, in any game, a profile  $\sigma$  is a *Nash equilibrium* [Nash50, Nash51] if in  $\sigma$  no player would unilaterally choose to deviate from his chosen action as this would diminish his payoff. Intuitively speaking, Nash equilibria model well stables states of a network, since if the network reaches such a configuration, most probably it would remain in the same configuration, since none of the involving entities has a motivation to change his status in order to be more satisfied. Thus, identifying Nash equilibria configuration of a network and evaluating them has been the main approach in order to analyze, evaluate networks performance [ACY05, ADTW03, CK05, KP99, MMP08, RT02].

Summing up, Game Theory and its various concepts of equilibrium provide a rich framework for modeling the behavior of selfish agents in distributed or networked environments. Moreover, it offers mechanisms to achieve efficient and desirable global outcomes given the selfish behavior of agents.

## 2.2. An Example Game: The Prisoners' Dilemma

The Prisoners' Dilemma [O94] game has two players (the prisoners): Bob and Al. Each of them has two possible strategies: to confess the other or not. Each of them should *simultaneously* decide which one of his strategies to follow (without knowing the choice of the other). Their choices determine their gain: If they both confess, each gets 10 years in prison, but if Al (resp., Bob) confesses and Bob (resp., Al) does not, Bob (resp., Al) gets 20 and Al (resp., Bob) goes free. Finally, if they both do not confess they both get 1 year in prison.

		AI	
		Confess	Don't Confess
Bob	Confess	10, 10	0, 20
	Don't Confess	20, 0	1, 1

Table 1. The Prisoners' Dilemma game.

Table 1 shows the players, the strategies and their payoffs (gain) for each of their strategy selections. Each prisoner can choose among one of the two strategies. In effect, AI chooses a column and Bob chooses a row. The two numbers in each cell tell the outcome for the two prisoners when the corresponding pair of strategies is chosen. The number to the left of the comma tells the payoff to the person who chooses the rows (Bob) while the number to the right of the column tells the payoff to the person who chooses the columns (AI). Thus (reading down the first column) if they both confess, each gets 10 years, but if AI confesses and Bob does not, Bob gets 20 and AI goes free.

Consider the following pair of strategies (*profile*) of the two players (*confess, confess*) corresponding to the strategy of AI and Bob respectively. Concerning AI, he gets 10 years in prison if he adopts this strategy, while he would get 20 years if he would not confess. Therefore his choice to confess is best for him. But the same reasoning holds also for Bob. Thus, the profile (*confess, confess*) consists best response strategies for all players of the game. This constitutes a Nash equilibrium of the game. Since all players use a single strategy in this profile, it is called *pure profile*.

Finding Nash equilibrium in this game seems to be not a difficult task. But in general games, there are more than two players involved with much more complicate payoff functions. This results to a significant increase of the difficulty to find Nash equilibrium. In particular, there are significant hardness results in finding pure Nash equilibria [FPT04], pointing to a whole complexity class (the PLS complexity class) which includes such searching tasks.

With regards to our approach to network security evaluation, a game is represented by a number of attackers and defenders that both aim to maximize their utility on the network, the former by maliciously degrading its performance and the latter by protecting it against attacks.

### 3. The Method

Assessing network security NFR is not a trivial task. An increasingly popular approach is to express this problem in the form of a game between attacker and defenders [AB04, B99, W08]. The former correspond to malicious software and the latter to defence software. When the designer starts thinking like an attacker, in essence he/she engages in a game with the attacker. Finding and evaluating equilibriums between attackers and defenders' strategies provide the mechanism to assess network's security. Therefore, this critical information can be provided during the design phase of a prospective network and hence, enable the designer to optimise network features accordingly.

The approach described in here is based on identifying Nash equilibria between attacker and defender strategies and in this way provide the means to assess the security level of prospective networks. These estimates can be subsequently used to validate security.

However, to validate a prospective network security NFR early in the design phase, prerequisite capturing its behaviour for all possible types of assaults. These combinations however, constitute a large number of possible test scenarios. Therefore, to evaluate the security performance of a prospective network we need to assess it against each of these possible test scenarios. Scenarios became a popular method for validating NFR [AS02, Car00] where each corresponds to a set of situations that might occur during the operation of a system. Application of scenarios in requirements validation has been performed by a number of researchers [AG05, AS02, AD93, ZJ00]. However, the main problem in requirements validation through scenarios is the specification of an adequate number of test cases. This however is a tedious and time consuming task. On the other hand, automated support for the scenario generation proved to be a vexed problem due to the exponentially large set of possible variations that needs to be examined [AG05] for the NFR to be guaranteed.

An approach that makes this problem tractable is described in here and is based on the application of game-theoretic analysis. In particular, we manage to reduce the number of scenarios needed to validate the NFRs by investigating only stable network states (configurations). This method is of polynomial time complexity compared to the size of the proposed network. Stable configurations describe the most likely states that a network could reside. Thus, by assessing security NFR in such states, we ensure the validity of the NFR almost always. Such states are very well captured through Nash equilibria profiles of the resulting game. Thus, we only utilize Nash equilibria in order to assess network security.

Our approach is composed of the following steps:

- 1) **Functional and non-functional security requirement specification:** Initially the network designer specifies quantitatively the required level of security of the future network as a percentage value. Moreover, the designer explicitly specifies the functional specification of the network in terms of security software capabilities and topology coverage.
- 2) **Modeling of the functional security and network requirements:** Model functional security requirement in the prospective network as a game played on a graph. In particular, we represent the network's topology using a graph and adopt a security game introduced in [MPPS05c]. According to this approach, the security threats and the potential defence mechanisms are realized by a set of confronting players on a graphical game.
- 3) **Validation of the non-functional security requirement:** We utilize the Nash equilibria identified and evaluated in [MPPS05c] to measure the security guarantee in the prospective network for both approaches. These represent a reduced set of test scenarios to be evaluated. Since Nash equilibria model well the stable configurations of the network, we ensure the validity of the NFR in the most probable states of the network. Evaluating of the Nash equilibria of the resulting game [MPPS05c] provides a novel validation method of the security NFR of prospective networks.

### 3.1. Case-study

We next illustrate the application of our method in an example network. The method is applicable in any network that fulfills the functional requirements specified a priori. The corresponding security NFR is initially defined as a percentage of the required level of security. Finding equilibria through Game Theory enables the designer to identify “stable” network configurations and subsequently evaluate whether these can archive the required level of security. The security NFR is satisfied if the assessed security meets the initial requirement. Therefore, the core problem in validating security is to firstly provide the means to assess it.

Our approach is based on the notion of *scenarios* [Car00], each describing possible configurations of attackers and defenders on the network. The use of Game Theory enables us to reduce the complexity of this process by analysing only scenarios that both attackers and the defender would choose given that they act *rationally*-they act in a way that aims to maximizes their benefit. Through game-theoretic analysis, strategies of both attackers and defenders on a network are modeled accordingly to assess the network’s security.

Next we illustrate the application of the method for a network characterized by a set of functional requirements.

#### 3.1.1. Functional Security Requirement Specification

A precondition for the method is that the network is of type “hit-all”. This means that the network  $N$  consists of an arbitrary number of nodes,  $n$  and a set of communication links  $E$  between the nodes of the network. Moreover, there exists a subset of the links  $E' \subseteq E$  such that each node  $v$  of the network is “hit” (incident) to *exactly* one link of the set  $E'$ . Note that a network with this property can be build and identified (that has fulfills the property) in polynomial time [LP86] (such a set is called a *Perfect Matching* of the network). We call such a network a *hit-all* network. For example, in the network of Figure 1, node  $v_1$  is hit by links  $e_1$ ,  $e_2$  and  $e_3$  shown with thick lines. Moreover, the thick links constitutes a hit-all set for that network.

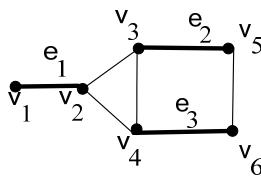


Fig. 1. An example of a network with a hit all set of links shown with thick lines.

We specify *network security specification* using a common process utilized in critical systems specifications [S05]. The process consists of the following components:

1. *Asset identification*: The assets of the network are the nodes of the network. In the most general case, all nodes are of the same importance. A node is considered protected or secure if a security software is installed on that node. Otherwise it is considered vulnerable to attacks.

2. *Threat analysis and assignment*: The prospective network may witness threats, such as viruses, Trojan horses and eavesdroppers [FAGY00] which are described as attacks that target the nodes of the network. At any time there is a maximum number of attackers,  $\alpha$ , that may be present in the network. Each of them damages nodes that are not protected. In the most general case, we have no information on the distribution of the attacks on the nodes of the network. So, we assume that attacks will follow a uniform distribution [T01], which is quite common in such cases. So, we assume that each attacker decides to attack or not a node of the network with the same probability. We call such attacks *uniform attacks*.

3. *Technology analysis*: One major security mechanism for protecting network attacks are the firewalls, that we refer to as defenders. Furthermore, in distributed firewalls [17] the network that is protected includes the links spanned by the nodes that participate in the distribution of the defenders. However, due to financial costs (e.g., the prohibitive cost of purchasing global security software) or from performance bottlenecks (e.g., the reduced usage of the protected part of the network) distributed mechanisms are only able to clean a limited part of the network. There are two possibilities with regards to the functional specification of the protection mechanism:

- (a) The simplest case is when the security mechanism resides on a single link of the network and hence protects the two nodes that the link connects.

We call this specification as *single-edge-protection* specification.

In this case we assume that the prospective network is supported by a *single* security software, denoted as  $d$ , which is able to clean a *single* link between two nodes from possible attackers at the endpoints of that link.

The distribution of defenders on the network's nodes exploits the topological property of the network as presented in the specification. That is, there is a set of links  $E'$  in the network such that any node is hit by (exactly) one link of that set. In particular, we assume defense mechanism chooses one link among that set  $E'$  with the same probability that is uniformly at random. We call this placement of the defense mechanism as *uniform-hit-all*.

- (b) In the general case when the security mechanism covers a set of links  $k$ , where  $k > 1$  but  $k < E$ . We call this specification as *multiple-edge-protection* specification.

So, in this case we assume that the network is supported by a security mechanism, denoted by  $d_k$ , which is able to clean a *set*  $k$  of links between two nodes from possible attackers at the endpoints of any link in the set.

In this case, there is a set of links  $E'$  in the network such that any node is hit by (exactly) one link of that set. It is assumed that the defense mechanism is placed on a set of  $k$  links among the set  $E'$ . We call this placement of the defense mechanism as *k-edges-hit-all*.

In this work we consider both *uniform-hit-all* and *k-edges-hit-all* that correspond to *single-edge-protection* and *multiple-edge-protection* accordingly security specification.



### 3.1.2. Modelling scenarios using Security and Network properties

This activity aims to assess the security NFR of the prospective network using a number of scenarios. A game theoretical model of the proposed network is presented and subsequently the necessary tools and notions that enable its security quantification are explained.

We model both network and security specifications presented in section 3.1.1. using two graph-theoretic games introduced and investigated in [MPPS05c, MPPS05b, MMPPS06]. The game is played on a graph  $G$  representing the network  $N$ . The players of the game are of two kinds: the *attackers* players and the *defender* players, representing the attacks and the security software of the network. The attackers play on the vertices of the graph, representing the nodes of the network. We consider two scenarios for the defenders:

- a) The defender plays on *the edges* of the graph, representing the links of the network. This case models the *single-edge-protection* security specification and calls this model *single-edge-protection game*.
- b) The defender plays on *sets of  $k$  edges* of the graph, representing sets of links of the network. This case models the *multiple-edge-protection* security specification and calls this model *k-edges-protection game*.

#### 3.1.2.1 Network Configurations

A *network configuration*  $s$  models the location (nodes) of attackers and defense mechanism (link or a set of links) on the network. The positioning of attackers and defenders may follow a probability distribution. That is, each attacker can target more than one node according to some probability distribution and similarly, the defense mechanism may protect more than one link according to another probability distribution. In such a case, have a *mixed* configuration of  $s$ . Otherwise, the configuration is said to be *pure*; one attacker on one node and the sole defender on one link. This constitutes another property of the scenario specification.

#### Example of the Single-edge-protection game.

Figure 2 illustrates a *mixed* configuration for an example network,  $N$  consisting of 8 nodes ( $n=8$ ). It can be seen that the network is a hit-all type. We assume that there exists 3 different attackers ( $\alpha=3$ ). According to the threat analysis of the security specification, the attacks are uniform; and hence, the probability of an attacker assaulting any node of the network is equal to  $1/n$  which is equal to  $1/8$ . In the Figure, attacker  $i$  is indicated by  $X_i$ .

Next, in the technology analysis of the security specification we designate that the security software mechanism is a *single-edge-protection*. Hence, modeled using the single-edge-protection game. Moreover, according to the security specifications, the security mechanism uses a uniform-hit-all probability distribution on a set of links  $E'$ . Recall that  $E'$  is such that any node of the network is hit by (exactly) one link of that set. So, the defender chooses each links of this set with probability  $1/|E'| = 1/4$ . In Figure 2, the links, as well as their corresponding visiting probabilities, are indicated by  $Y$  and thick lines.

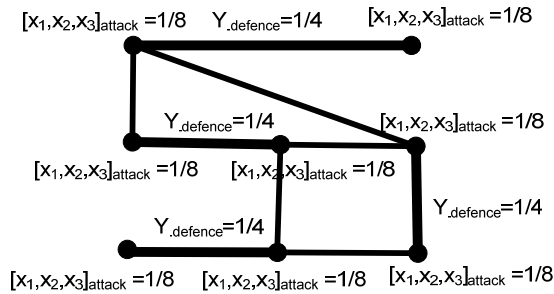


Fig. 2. An example of a network configuration for the Single-edge-protection game. We assume that there exists 3 different attackers ( $\alpha=3$ ). Each attacker is indicated by X. Each attacker targets any node of the network with probability 1/8. The security software chooses among a subset of links  $E'$  to clean them from possible attacks, uniformly at random. The links consisting the set  $E'$ , and their corresponding visiting probabilities, are indicated by Y in thick lines. So, each link in the set is visited by the security software with probability 1/4. The assessed security level of this scenario is equal to 25%.

**Example of the k-edges-protection game.**

Figure 3 illustrates a network configuration for the same sample network of Figure 2 and the same scenario assumptions for the attackers. The scenario specification for the security software mechanism is defined as a *multiple-edge-protection*. Hence, modeled in a k-edge-protection game. Here, we assume that  $k=n/2$ . Moreover, according to the security specifications, the set of edges  $E'$ , that the defense mechanism can clean simultaneously, constitute a *k-edges-hit-all* set. That is, any node of the network is hit by (exactly) one link of the set  $E'$ . In Figure 3, the links of the set  $E'$  are indicated by thick lines.

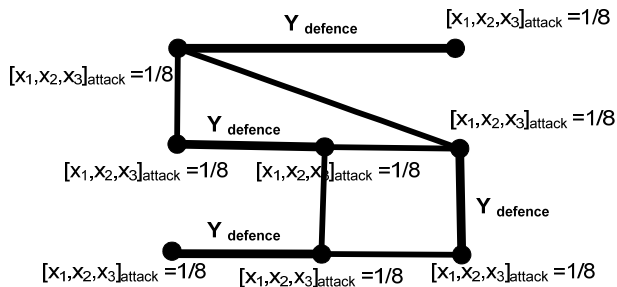


Fig. 3. An example of a network configuration for the k-edges-protection game. In this case the defense mechanism can clean k links at the same time; that is  $k=n/2$ . Also, the defense mechanism is placed on a set of links  $E'$  such that the set is a *k-edges-hit-all* indicated with thick lines. The assessed security level of this scenario is equal to 100%.

### 3.1.3. Validation of the Non-functional Security Requirement

#### 3.1.3.1 A Game-Theoretic Security Measurement

To evaluate network security it is necessary to assess the security level of an arbitrary profile (configuration) of the defined game of the prospective network similarly with [MPPS05c, MPPS05b, GMPPS06]. Therefore, consider a pure network configuration  $s$ . Let  $s_d$  be the edges defended by the security software. For each attacker  $i \in [\alpha]$ , let  $s_i$  be the node in which the attacker strikes. We say that the attacker  $i$  is *killed* by the security mechanism if the node  $s_i$  is one of the two endpoints of the link  $s_d$  being defended by the security software. Then, the *defense ratio* [MMPPS06] of the configuration  $s$ , denoted by  $r_s$  is defined to be as follows, when given as a percentage:

$$r_s = \frac{\text{number of attackers killed in } s}{a} \times 100. \quad (1)$$

For a mixed network configuration, the *defense ratio* [MMPPS06] of the configuration,  $r_s$  is defined as:

$$r_s = \frac{\text{expected number of attackers killed in } s}{a} \times 100. \quad (2)$$

From the above, the optimal defense ratio of a network equals to 100 if the security software manages to kill all attackers. In such a case we specify that the network configuration obtains 100% security level. The larger the value of  $r_s$ , the greater the security level obtained. Through this approach, we assess the security level of perspective networks by only examining *stable* configurations and hence limited scenarios. Given that, whenever the network reaches a stable a configuration it *tents* to remain in that configuration, highlights the significance of evaluating scenarios that emerge from this to assess its security NFR. This is because in such configurations no single player has an incentive to unilaterally deviate from its current strategy. So, such configurations constitute the most probable states of the network and hence we use these to define the test scenarios based on which to assess security. Therefore, we escape from the NP-hard problem of having to assess each possible configuration or scenario. We identify such stable configurations evaluate the network security on them. Thus, this measurement constitutes a *representative* assessment of the security level of prospective networks.

Considering that the network designer wishes to achieve a security level of 90%, the following procedure is used to assess the security level for different network configurations. The main constrain of the approach is that it limits its scope to hit-all type networks.

Initially, we identify stable configurations resulting from the specifications by the Nash equilibria found in the game of [MMPPS06]. Thus, in order to evaluate network security we evaluate the Nash equilibria of the game of [MPPS05c, MPPS05b]. Indeed they showed a result which is interpreted in our terms as follows:

**Theorem 1.** [MMPPS06] *Consider a network  $N$  with  $n$  nodes such that the network and security and functional and non-functional specifications of Section 3.1.1 (case (a) of Technology analysis of Section 3.1.1) are satisfied. Then the network contains a stable configuration (i.e. a mixed Nash equilibrium)  $s$  where the expected number of attackers killed is  $2/n$ . So, the defense ratio here is :*

$$r_s = \frac{2}{n} \times 100 \quad (3)$$

The result combined with equation (1) above implies that the network of Figure 1 has security level equal to  $2/n \times 100 = 2/8 \times 100 = 25\%$ , since  $n=8$ . This designates that the level of security is 25% given the functional requirements specified in configuration  $s$ . This assessment however indicates that the initial NFR specified by the designer is not satisfied using the prescribed functional requirements of the network as is. Hence, the network specification needs to be revised and the security NFR revalidated, prior to implementation.

We also use the following result:

**Theorem 2.** [GMPPS06] *Consider a network  $N$  with  $n$  nodes such that the network and security and functional and non-functional requirements given in section 3.1 (b) are satisfied and  $k=n/2$ . Then the network contains a stable configuration (i.e. a Nash equilibrium)  $s$  where all attackers are killed. So, the defense ratio is*

$$r_s = \frac{a}{a} \times 100 = 100 \quad (4)$$

The result implies that the network of Figure 2 has security level equal to 100% (recall that  $k=n/2$  here) given the functional requirements specified in configuration  $s$ . This assessment indicates that the NFR specified by the designer a priori is now satisfied using the prescribed functional requirements of the network.

## 4. Conclusion

Security requirements validation is traditionally performed through security-specific testing. Ideally, validation should be performed on all possible network conditions expressed by test scenarios. However, examining all possible scenarios [AD93, AS02] to validate security requirement early in the design phase of a prospective network, constitutes a highly complex and sometimes infeasible task. In this work we manage to accomplish this process in only polynomial time. This is achieved by considering only stable configurations of the system, that we model using Nash equilibria. This yields in a limited set of test scenarios that guarantee the assessment of network's security level. In this context, the method presented in this paper constitutes a novelty in validating security NFR through game theory.

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# Constructing geo-information sharing GRID architecture

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## 1. Introduction

Along with the development of Internet, Geo-information Sharing and Open GIS are of increasing importance for GIS application fields. Spatial Information Grid (SIG) is the fundamental application of Grid technology in spatial information application service domain. This chapter presents a pilot platform for Resource and Environment Geo-information Sharing for Southwestern China based on Web Services, .NET, OGC, Web GIS, SIG, and Mobile Agent is constructed. The architecture in the pilot platform consists of 3 tiers: application layer, service layer and resource layer. Via the pilot platform, distributed heterogeneous geo-information, software and hardware resource from four provinces and one municipality in Southwestern China is integrated.

Geospatial data is the major type of data that human beings have collected. Geospatial data and information are significantly different from those in other disciplines. How to effectively, wisely, and easily use the geospatial data is the key information technology issue that we have to solve.

Along with the development of Internet, Geo-information Sharing and Open GIS are of increasing importance. Grid technology is developed for general sharing of computational resources and not aware of the specialty of geospatial data. Spatial Information Grid (SIG) is the fundamental application of Grid technology in spatial information application service domain. This paper presents a pilot platform for Resource and Environment Geo-information Sharing Architecture for the Southwestern China based on Web Services, Open GIS, Spatial Information Grid and OGSi.Net.

### 1.1. Open Geographical Information Systems

In (Panagiotis A. Vretanos. 2005), Open GIS Consortium (OGC) thinks that Interoperability is the “capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units.” There are many methods of information

communications, such as CGI (Common Gateway Interface), Server API (Application Programming Interface), Plug-in GIS, Java Applet, ActiveX and COM (Component Object Model).

The distributed geographic information sharing technology includes three models, which are Microsoft's DCOM (Distributed Component Object Model)/ActiveX, Sun's Java/RMI and OMG's (object management group) CORBA (common object request broker architecture). The ActiveX/DCOM model only runs on the Microsoft Windows platform, and Java/RMI technology localizes on the Java language. In despite of the independency of languages and Operate Systems, CORBA adapts to construct the distributed systems of compact coupling.

In a sense, Web Services extend the distributed Objects/Component technology. By contrast with the former Interoperable methods, Web Services accomplish the accesses to objects in the loose coupling circumstances. Web components can implement and publish in any computer which provides corresponding functions and services, and also integrate the heterogeneous applications. Therefore, the technology of Web Services adapts to share the Geo-information of heterogeneous GISs.

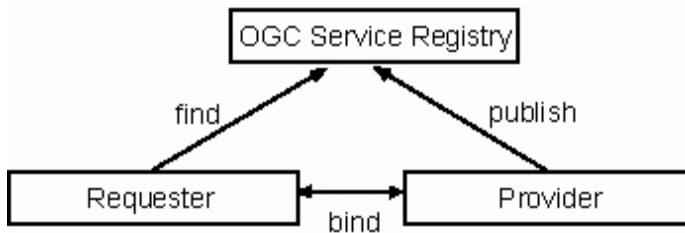


Fig. 1. Three roles in Web Service

Web Services, which are the product of the Internet, publish the standard interfaces of functions or services. The protocols such as Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL) and universal Description, Discovery and Identification (UDDI) provide the architecture for simple, yet effective GIS interoperability independent of concrete platforms and softwares. UDDI's aim is to develop a standard for an online registry, and to enable the publishing and dynamic discovery of Web services offered by businesses. Web Service Architecture includes three roles (as illustrated in Fig. 1.): Service Provider, Service Registry (or Service Broker), and Service Requester. Service Provider is the provider of the web service. The provider implements the service, and makes it available on the Internet. Service Requester is any consumer of the web service. The requestor utilizes an existing web service by opening a network connection and sending an XML request. Service Registry is a logically centralized directory of services. The registry provides a central place where developers can publish new services or find existing ones. It therefore serves as a centralized clearinghouse for companies and their services. The roles communicate through three behaviors: Publish, Find, and Bind.

Provider entity may describe a service with WSDL, and then may register the service in Registration Center (such as OGC Service Registry). Request may find the description of a service in Registration Center, and then bind with the Provider that publishes the service. Request may communicate with Provider each other, and may invoke the service.



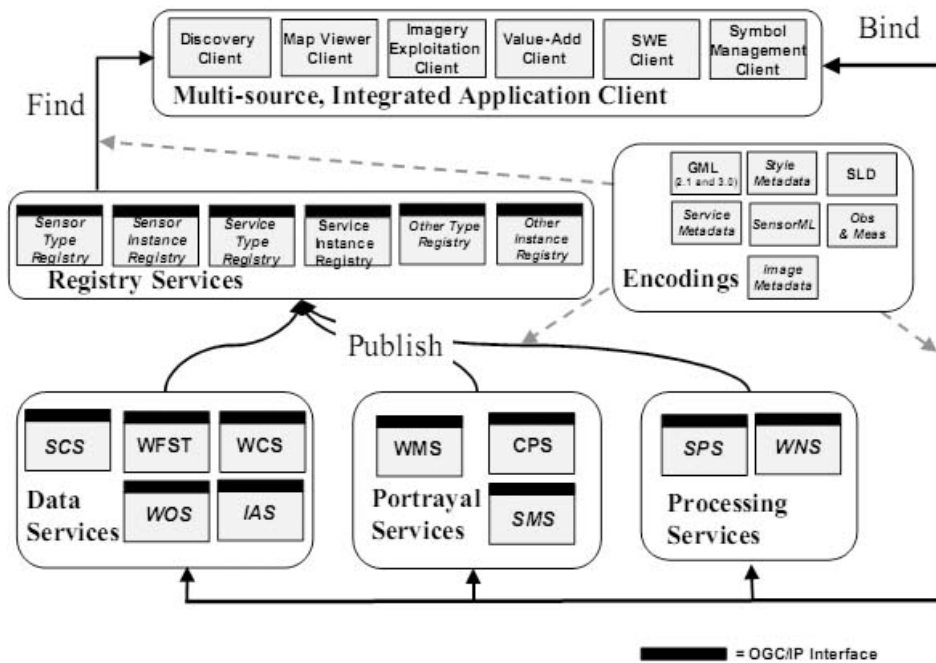


Fig. 2. Architecture of GIS based on Web Service

In (Joshua Lieberman. 2003), the OpenGIS Services Framework (as illustrated in Fig. 2.) provides the common set of interfaces that spans these functional parts of the enterprise and provides enterprise-wide interoperability.

The elements of the architecture are listed as follows:

**Client Services** - the client-side components of client applications that interact with users, and on the server-side interact with Server-side Client Applications, Application Servers and Data Servers.

**Registry Services** - provides a common mechanism to classify, register, describe, search, maintain and access information about network resources (data and services). Registry Services include Web Registry Service (WRS).

**Processing-Workflow Services** - the foundational application-building-block services that operate on geospatial data and metadata, providing value-add service. Processing-Workflow Services include Sensor Planning Service (SPS) and Web Notification Service (WNS).

**Portrayal Services** - Portrayal Services provide specialized capabilities supporting visualization of geospatial information. Portrayal Services are components that, given one or more inputs, produce rendered outputs such as cartographically portrayed maps, perspective views of terrain, annotated images, views of dynamically changing features in space and time, etc.). Portrayal Services include Web Map Service (WMS), Coverage Portrayal Service (CPS) and Style Management Service (SMS).

**Data Services** - The foundational service building blocks that serve data, specifically geospatial data. Data Services include Web Object Service (WOS), Web Feature Service

(WFS), Sensor Collection Service (SCS), Image Archive Service (IAS) and Web Coverage Service (WCS).

The OGC (Open GIS Consortium) constitutes three principal interoperable specifications to access Web Services, which are Web Map Server (WMS) as well as the Web Coverage Server (WCS) and the Web Feature Server (WFS). A Web Map Service produces maps of geo-referenced data. This WMS specification (Praveen Ummadi) defines three WMS operations: GetCapabilities (required) returns service-level metadata, which is a machine-readable (and human-readable) description of the WMS service's information content and acceptable request parameters; GetMap (required) returns a map image whose geospatial and dimensional parameters are well-defined; GetFeatureInfo (optional) returns information about particular features shown on a map. A "map" defined as a visual representation of geo-data is not the data itself. The WFS operations support INSERT, UPDATE, DELETE, QUERY and DISCOVERY operations on geographic features using HTTP as the distributed computing platform. In (Boucelma et al, 2002), this WFS specification (Boucelma et al, 2002) defines two kinds of WFS operations: Basic WFS and Transaction WFS. A basic WFS would implement three WFS operations: GetCapabilities (required) describe the capabilities of a web feature service such as which feature types it can service and what operation are supported on each feature type; DescribeFeatureType (required), upon request, describes the structure of any feature type a web feature service can service; GetFeature (required) services a request to retrieve feature instances, when the client specifies which feature properties to fetch and constrains the query spatially and non-spatially. The Basic WFS is considered a READ-ONLY web feature service. A transaction WFS supports all the operations of a Basic WFS and in addition it implement the Transaction operation. A transaction request is composed of operations that modify features; that is CREATE, UPDATE, and DELETE operations on geographic features. Optionally, a transaction WFS could implement the LockFeature operation that process a lock request on one or more instances of a feature type for the duration of a transaction. This ensures that serial transactions are supported.

At present, many GIS applications are independent of each other, and are not interoperable. ArcIMS, ESRI's Web mapping server technology has its own XML protocol, ArcXML utilized to communicate between ArcIMS client and ArcIMS server. ESRI's MapObjectsIMS, which provides clients with images of geo-data, is a tool to develop Web GIS. AutoDesk's Mapguide deals with requests from Mapguide Viewer, and returns the geo-data. Intergraph's GeoMedia transmits ActiveCGM to clients and makes vector maps. These GIS softwares receive respective requests from their own clients. ArcIMS and MapObjectsIMS servers return images of geo-data, Mapguide and GeoMedia servers provide vector maps. It is difficult to interoperate the applications and the geo-data of these GISs.

## 1.2. Spatial Information Grid

In (S. Tuecke et al., 2003), (Ian Foster & Carl Kesselman, 1999) and (Ian Foster et al, 2002), the term "Grid" was coined in the mid-1990s to denote a proposed distributed computing infrastructure for advanced science and engineering. "Grid" computing has emerged as an important new field, distinguished from conventional distributed computing by its focus on large-scale resource sharing, innovative applications. The concept of the "SIG" (spatial information grid) which was put forward based on the grid computing, is the fundamental plan and useful tool to construct the Geo-information sharing. SIG is an intelligent

information platform which is built based on the current spatial information infrastructure and spatial information network protocol specification and from which the user can obtain the common spatial information services conveniently. The procession of the spatial information in this platform is distributing collaborated and intelligent in this platform, and user can visit all spatial information via the common protocol and do not need to know the information he needed from million website from internet.

In (I. Foster et al, 2005), Global Grid Forum think that grid systems and applications aim to integrate, virtualize, and manage resources and services within distributed, heterogeneous, dynamic "virtual organizations". The realization of this goal requires the disintegration of the numerous barriers that normally separate different computing systems within and across organizations, so that computers, application services, data, and other resources can be accessed as and when required, regardless of physical location. The Open Grid Services Architecture (OGSA) is a service-oriented architecture. It is intended to facilitate the seamless use and management of distributed, heterogeneous resources. In this architecture, the terms "distributed," "heterogeneous" and "resources" are used in their broad sense. For example: "distributed" could refer to a spectrum from geographically-contiguous resources linked to each other by some connection fabric to global, multi-domain, loosely- and intermittently-connected resources. "Resources" refers to any artifact, entity or knowledge required to complete an operation in or on the system.

Building on both Grid and Web Services technologies, the Open Grid Services Infrastructure (OGSI) defines mechanisms for creating, managing, and exchanging information among entities called Grid services. In a word, a Grid Service is a Web Service that conforms to a set of conventions (interfaces and behaviors) that define how a client interacts with a Grid Service.

Web Services address the discovery and invocation of persistent services, and offer a powerful application-to-application integration framework. Web Services miss state management, global service naming, reference resolution and common behaviors and semantics defined for services by some interface description language. Web Services are stateless. In contrast, Grid Services are stateful Web Services. Grid Services are the glue that transforms a collection of distributed, independent resources into a coherent computation, storage, and collaboration fabric. They provide uniform mechanisms for user authentication and authorization, accounting, resource access, data transfer, system monitoring, and resource management. Grid Services make it possible for users, applications, and tools to discover and use disparate resources in coordinated ways.

In (Glenn Wasson et al, 2004), the basic design of OGSI.NET is to have a container entity that "holds" all the service instances running on a host. As illustrated in Fig. 3, the container process consists of a collection of Application Domains (or AppDomains), Microsoft's mechanism for intra-process memory protection. Each service instance executes in its own AppDomain and there is one additional domain for the container's logic (some dispatching and message processing functionality).

A client makes a request on the OGSI.NET architecture by sending a message to the IIS web server. In order to support arbitrary names for grid services, OGSI.NET uses an ISAPI filter to intercept requests at an early stage in the IIS request chain. This filter re-writes the request so that IIS will dispatch it to OGSI.NET's ASP.NET HttpHandler. This HttpHandler dispatches the request to the OGSI.NET container. The container process has a thread pool and each IIS request causes one of the container process' threads to execute the dispatcher.

The dispatcher determines which service instance should get the request and transfers execution of that thread to an object in the appropriate AppDomain.

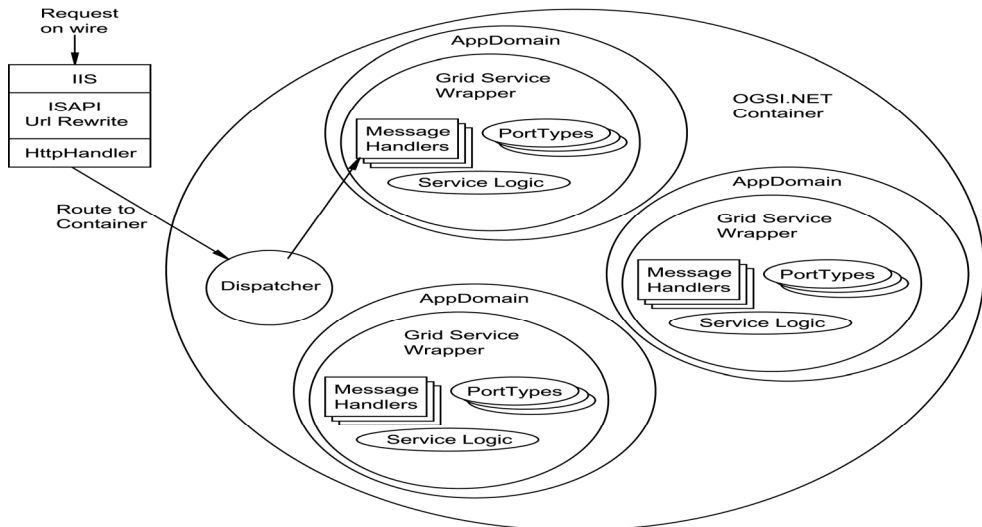


Fig. 3. OGSi Container on the .Net Platform

### 1.3. Mobile Agent Technology

In (D. Chess et al, 1994), mobile agent is considered as an enabling technology for automated, flexible and customized service provision in a highly distributed way as network nodes become active and take part in the computation of applications and provision of customized services. Besides the clear separation among the key functionality and the aspects of deployment on the functional side, Mobile Agent can offer potential technical advantages. Among them are reduced communication cost, reduced bandwidth usage, the possibility of using remote interfaces and the support for off-line computation. Mobile agents enable both temporal and spatial distribution of the service logic, which makes another technical advantage, namely scalability, while at the same time bottlenecks of centralized approaches such as reduced network availability and malfunctioning are avoided (A. Puliafito et al, 2001). With the capabilities mentioned above, Mobile agents can provide a suitable framework for spatial data resource and service discovery in grid platforms, and can support optimal access and interaction through heterogeneous terminals, differing in terms of memory capacity, computational resources, display characteristics, allowed connection mode, etc (A. L. Corte et al, 1999).

In (Jian Ma et al, 2006), the architecture with the convergency of Mobile Agent and Spatial Data Grid is constructed. A middleware layer allowing users to access distributed resources in a transparent, secure and effective way is proposed. The Grid middleware is integrated with functions to make data mining and data transferring easier. And the mobile agent that manages the user and the issues related with the heterogeneity of the devices is applied.

The agents provided by the system are classed into two types: user agent, carrying users' requests for spatial data; information agent, representing information of distributed spatial

data resources and providing spatial data services for other agents. Otherwise, Agency Agent is proposed to settle distributed transparency of system. Agents could communicate with Agency Agent and obtain other agents' information (attribute, location, and resources, etc), and then move to the resource node located and complete corresponding work. The Mobile Agent system consists of a set of agent subsystems and the agency agent system whose task is to manage the information of all agent subsystems. The agent subsystem which includes User Agent, Native Query Agent and Collaboration Query Agent is interactive and distributed. The system architecture is shown in Fig.4.

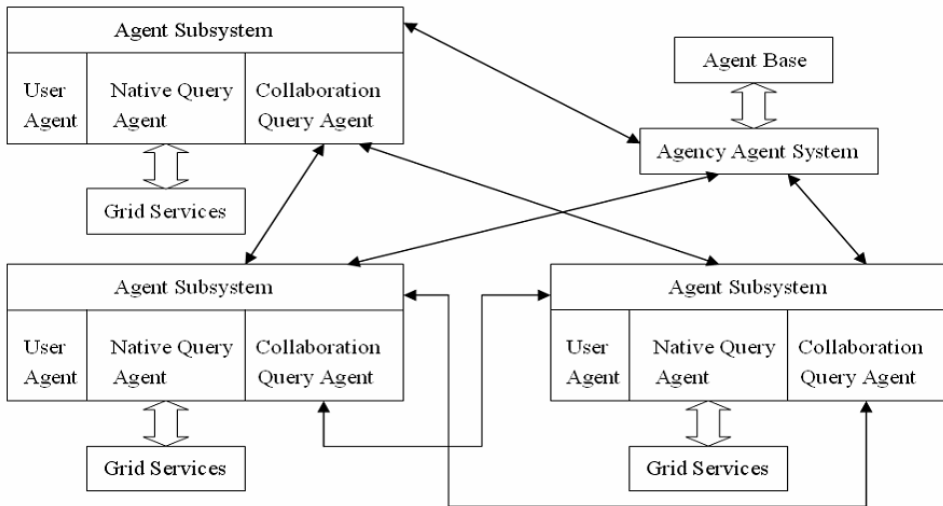


Fig. 4. the Geo-information sharing Grid architecture based on Mobile Agent

Agency Agent (AA), playing the most important role in the whole system, is the key technology to solve the requirement of distributed transparency. The task of Agency Agent is to collect, manage, query all agents' information, and at one time act as a dependable secure authentication center to ensure communication among those agent subsystems. The information Agency Agent needs is provided by information base of agents.

User Agent (UA) has the main task of providing the user with the services he wishes. User Agent which has friendly user interface can accept spatial data requests from users and return them results. User Agent is able to transform users' requests into commands which could be identified by other agents, and search correlative information agent automatically. The process between putting forward requests and returning results is transparent for users.

Native Query Agent (NQA) accepts request from User Agent, and communicates with native spatial data services which are built up in the grid environment to obtain information needed. Native Query Agent is founded by User Agent and runs in background. Native Query Agent is also transparent for users.

Collaboration Query Agent is a mobile agent. It accepts collaboration information query requests from User Agent, gets the address of target agent subsystem from Agency Agent, then moves to target host computer and completes the information query task.

The whole process for information query is described as follows:

- 1) A request for spatial data is sent to User Agent via web explorer.
- 2) A request for native information query is sent to Native Query Agent by User Agent.
- 3) When the native information query is accomplished, the collaboration information query is provided. First, Collaboration Query Agent asks Agency Agent for other agent subsystems' profile information.
- 4) When gets other agent subsystems' context information, Collaboration Query Agent dispatches a mobile agent which carries corresponding request to the spatial information node located, then the mobile agent asks for native information query in the target agent subsystem's context and returns the result.

Java is adopted in the whole system's implementation to meet platform-independence. Grid environment is built up with Globus Toolkit 4, which is based on Java. Agents' mobility and interoperability is met by Aglets which is based on Java. Dynamic web page and function of User Agent is implemented by Servlet which is based on Java. The communication among agents is actualized by Aglets' message system which is also based on Java.

## 2. Framework of the resource and environment Geo-information sharing architecture based on Web Services

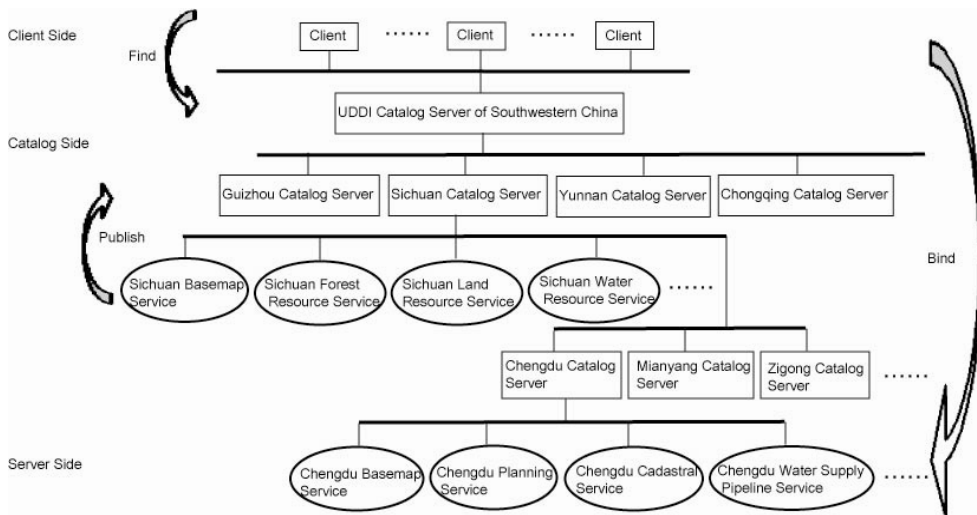


Fig. 5. The resource and environment Geo-information sharing architecture for the Southwestern China

Web service is a stateless service. The Resource and Environment Geo-information Sharing Architecture for the Southwestern China presented in (LIU Qiang & CHENG Boyan, 2006) is based on Web service. It integrates resource and environment geo-information from four provinces and one municipality in the Southwestern China. The framework is illustrated in Fig. 5.

This architecture in the pilot platform consists of 3 tiers (as illustrated in Fig. 4): Client side, Catalog side and Server side. Catalog side is a multi-level tree structure. The top node is a

UDDI Catalog Server of Southwestern China, which owns several children nodes, Guizhou Catalog Server, Sichuan Catalog Server, Yunnan Catalog Server and Chongqing Catalog Server. These children nodes also own several their own children nodes, respectively. For example, Sichuan Catalog Server’s children nodes are Chengdu Catalog Server, Mianyang Catalog Server, and Zigong Catalog Server, etc. All Services in Southwestern China are separated into several cases corresponding to UDDI Catalog Servers. For instance, Provincial Services such as Sichuan Basemap Service, Sichuan Forest Resource Service, Sichuan Land Resource Service, and Sichuan Water Resource Service as well as the children Catalog Servers are registered into Sichuan Catalog Server. Municipal Services such as Chengdu Basemap Service, Chengdu Planning Service, Chengdu Cadastral Service and Chengdu Water Supply Pipeline Service as well as the children Catalog Servers are registered into Chengdu Catalog Server. Thus, users can access all services via the UDDI catalog servers tree conveniently.

### 2.1. System Structure Platform Architecture

The stateless architecture in the pilot platform consists of 3 tiers (as illustrated in Fig. 6): client side, catalog side and server side. The server side as service provider publishes and registers services to the catalog side. It includes multiple web sites which provide services of geo-data (base map database, forest, land-use, mineral, disaster and water resources, etc.) and mapping functions (Qiang Liu et al, 2005).

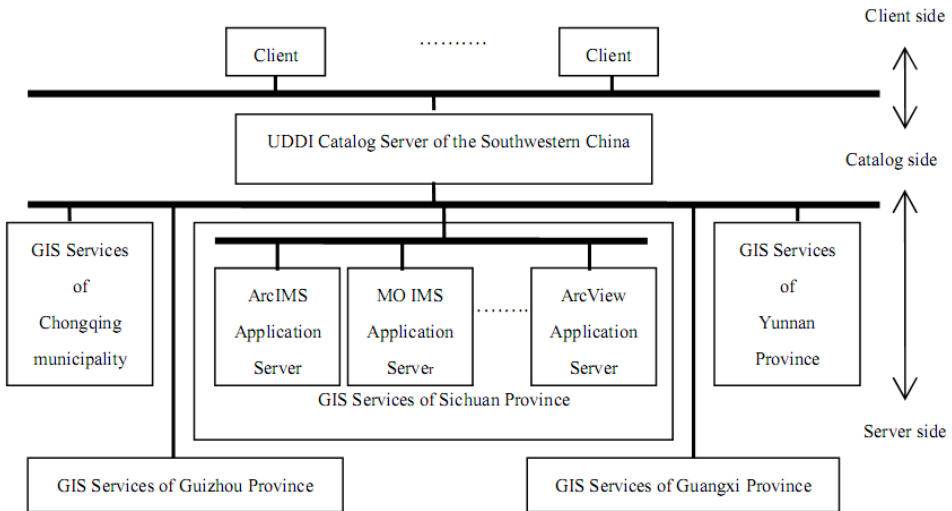


Fig. 6. The 3tiers architecture in the pilot platform

As a service requester, the client side makes the OGC WMS-compliant command to inquire geo-data and services. It finds the service description in the catalog side, then binds the service provider and invokes the service. At last, the client side displays the result and the image. The client side communicates with the server side via SOAP.

## 2.2. System Function

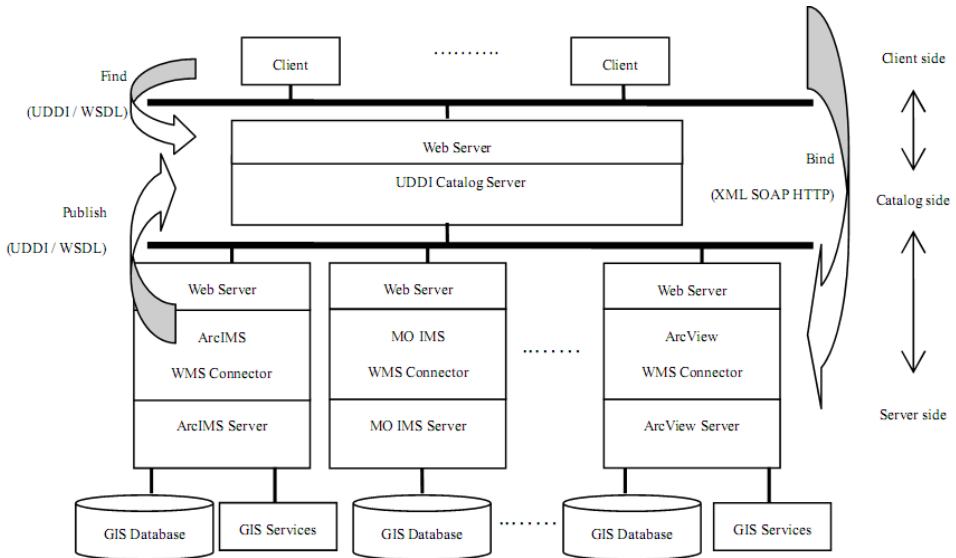


Fig. 7. the Geo-information Sharing Architecture Based on WMS

In the Resource and Environment Geo-information Sharing Architecture based on WMS (as illustrated in Fig. 7), the server side that includes WMS connectors publishes and registers services to the catalog side. Firstly, the server side describes services in WSDL, organizes metadata, and publishes the documents to the catalog side via UDDI. In the client side, a user browses uniform graphics interface and chooses service scopes such as districts and layers. The client side makes a WMS-compliant search request (or a series of searches), and sends it to the catalog side. The request is first handled by the Web server (such as Microsoft IIS), and then submitted to the catalog server in the catalog side. According to the request, the catalog server searches from the index tree of service metadata, returns the description of the specific services. According to the description, the client side makes the WMS-compliant image request, and then sends the image request to the server side. The web server of the server side parses the request, and then invokes the service provided by GIS server through the WMS connector. The service invoked by the web server handles the geo-data and produces an image. Then the image is sent to the web server through the WMS connector, transferred to the client side in succession.

In the Resource and Environment Geo-information Sharing Architecture based on WFS (as illustrated in Fig. 8), the server side that includes WFS connectors publishes and registers services to the catalog side. The client side makes a WFS-compliant search request (or a series of searches), and sends it to the catalog side. According to the description returned from the catalog side, the client side makes the WFS-compliant geographic features request, and then sends the geographic features request to the server side. The web server of the server side parses the request, and then invokes the service provided by GIS server through the WFS connector. The service invoked by the web server handles the geo-data and produces a shape file and a feature properties file include geographic features requested.



Then the files are sent to the web server through the WFS connector, transferred to the client side in succession, and then displayed the map of the requested geographic features (as illustrated in Figure 4).

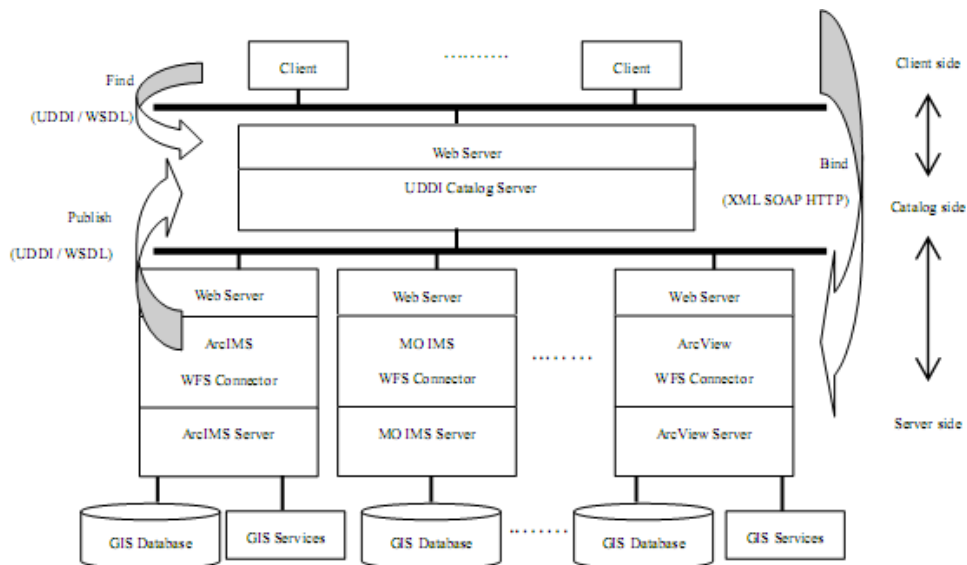


Fig. 8. the Geo-information Sharing Architecture Based on WFS

### 2.3. Key Technologies

The service metadata in the sharing platform is published in the catalog side. Along with the increase of service metadata, it is important to design a method to organize and inquire the metadata. The service metadata is stored in a structure of an index tree. A node of the index tree stores services that handle geo-data in the same geographical coordinate scope. According to the spatial scope of requests, the catalog server recursively searches for the corresponding service from the root node to leaf nodes of the metadata index tree.

Making WMS connectors is one key of constructing the sharing platform. For each type of Web GIS software used in the architecture, a respective WMS connector is needed. In the circumstance of Microsoft .NET, ISAPI program is a DLL file that separately runs in a server. In this platform, we have built three WMS connectors: ArcIMS WMS connector, ArcView WMS connector and MO-IMS WMS connector. The ArcIMS WMS connector developed as ISAPI is used to transmit WMS-compliant requests to the ArcIMS server side. The ArcIMS WMS connector receives the WMS-compliant requests from web server, as followed.

`http://serverIP/Scripts/GetMap.dll?SERVICENAME=servicename&REQUEST=GetMap&LAYERS=layerlist&STYLES=stylelist&SRS=namespaceidentifier&BBOX=minx,miny,maxx,maxy&WIDTH=outputwidth&HEIGHT=outputheight&FORMAT=outputformat&TRANSPARENT=0&BGCOLOR=0xFFFFFFFF&EXCEPTIONS=SE_XML&&VERSION=1.1.0`

Then, the ArcIMS WMS connector transfers them to the ArcIMS-compliant requests that consist of the requests URL and the ArcXML file. The requests URL is:

<http://ArcIMSserverIP/servlet/com.esri.esrimap.Esrimap?>

[ServiceName=servicename&ClientVersion=4.0](http://ArcIMSserverIP/servlet/com.esri.esrimap.Esrimap?ServiceName=servicename&ClientVersion=4.0)

The ArcXML file is:

```
<?xml version='1.0' encoding='UTF-8' ?>
<ARCXML version='1.1'>
  <REQUEST>
    <GET_IMAGE show="layerlist">
      <PROPERTIES>
        <ENVELOPE minx="minx" miny="miny" maxx="maxx" maxy="maxy" />
      </PROPERTIES>
    </GET_IMAGE>
  </REQUEST>
</ARCXML>
```

At last, the ArcIMS WMS connector submits them to ArcIMS server. With such specific WMS connectors, a united WMS-compliant client interface and a catalog side used to serve for both the WMS-compliant client side and the server side can be built. Then, the Resource and Environment Geo-information Sharing Architecture in the Southwestern China with a 3-tier WMS-compliant Web Service can be implemented.

Making WFS connectors is the other key of constructing the sharing platform. For each type of Web GIS software used in the architecture, a respective WFS connector is needed. In the circumstance of Microsoft .NET, ISAPI program is a DLL file that separately runs in a server. In this platform, we have built three WFS connectors: ArcIMS WFS connector, ArcView WFS connector and MO-IMS WFS connector. The ArcIMS WFS connector developed as ISAPI is used to transmit WFS-compliant requests to the ArcIMS server side. The ArcIMS WFS connector receives the WFS-compliant requests from web server, as followed.

[http://serverIP/Scripts/GetFeature.dll?SERVICENAME=servicename&REQUEST=GetFeature&LAYERS=layerlist&STYLES=stylelist&SRS=namespaceidentifier&BBOX=minx,miny,maxx,maxy&WIDTH=outputwidth&HEIGHT=outputheight&FORMAT=outputformat&TRANSPARENT=0&BGCOLOR=0xFFFFFFFF&EXCEPTIONS=SE\\_XML&&VERSION=1.1.0](http://serverIP/Scripts/GetFeature.dll?SERVICENAME=servicename&REQUEST=GetFeature&LAYERS=layerlist&STYLES=stylelist&SRS=namespaceidentifier&BBOX=minx,miny,maxx,maxy&WIDTH=outputwidth&HEIGHT=outputheight&FORMAT=outputformat&TRANSPARENT=0&BGCOLOR=0xFFFFFFFF&EXCEPTIONS=SE_XML&&VERSION=1.1.0)

Then, the ArcIMS WFS connector transfers them to the ArcIMS-compliant requests that consist of the requests URL and the ArcXML file. The requests URL is:

<http://ArcIMSserverIP/servlet/com.esri.esrimap.Esrimap?ClientVersion=3.1&ServiceName=servicename&CustomService=Extract>

The ArcXML file is:

```
<?xml version='1.0' encoding='UTF-8' ?>
<ARCXML version='1.1'>
  <REQUEST>
    <GET_EXTRACT>
      <PROPERTIES>
        <ENVELOPE minx="minx" miny="miny" maxx="maxx" maxy="maxy" />
      </PROPERTIES>
    </GET_EXTRACT>
  </REQUEST>
</ARCXML>
```

At last, the ArcIMS WFS connector submits them to ArcIMS server. With such specific WFS connectors, a united WFS-compliant client interface and a catalog side used to serve for both the WFS-compliant client side and the server side can be built. Then, the Resource and Environment Geo-information Sharing Architecture in the Southwestern China with a 3-tier WFS-compliant Web Service can be implemented.

### 3. Framework of the resource and environment Geo-information sharing architecture based on Spatial Information Grid

The Resource and Environment Geo-information Sharing Architecture for the Southwestern China based on GRID presented in this section integrates distributed heterogeneous geo-information, software and hardware resource from four provinces and one municipality in the Southwestern China (Qiang Liu & Boyan Cheng, 2009).

#### 3.1. System platform architecture

The architecture in the pilot platform consists of 3 tiers (as illustrated in Fig. 9): application layer, service layer and resource layer.

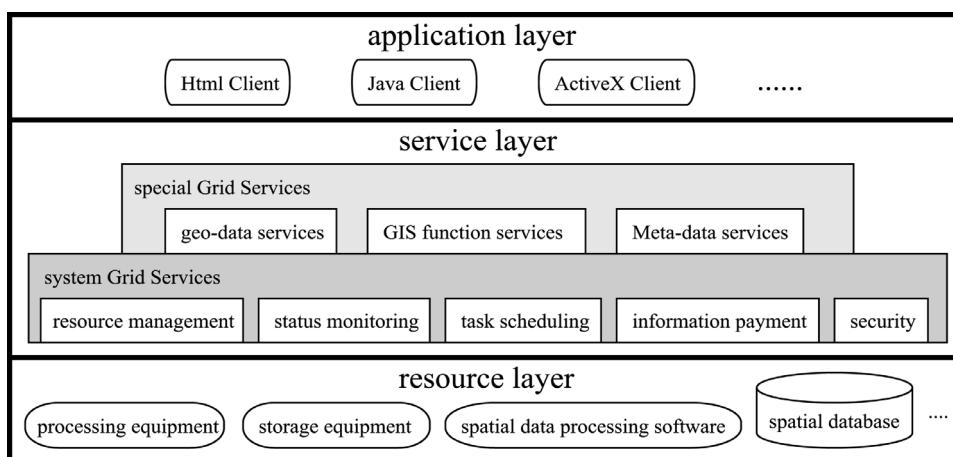


Fig. 9. Resource and Environment Geo-information Sharing Architecture

The resource layer includes storage resource-multiple spatial databases which provide geodata (base map database, special map database, etc.), various GIS softwares (ArcIMS, ArcMap, etc.), and disposal equipment (such as computers).

The resources are connected via facilities of Internet or wireless communication. The service layer, which builds on the resource layer, provides a management platform of integrative spatial information, and comprises system services and special services.

The application layer can request Grid Services of geodata or functions and browse maps via uniform user interface.

The service layer is the core layer of the Resource and Environment Geo-information Sharing Architecture based on GRID. The system Grid Services in the service layer, manage and maintenance the sharing platform. They are composed of resource management service,

security service, task scheduling service, monitoring service and payment service. The special Grid Services include geodata services and GIS processing services.

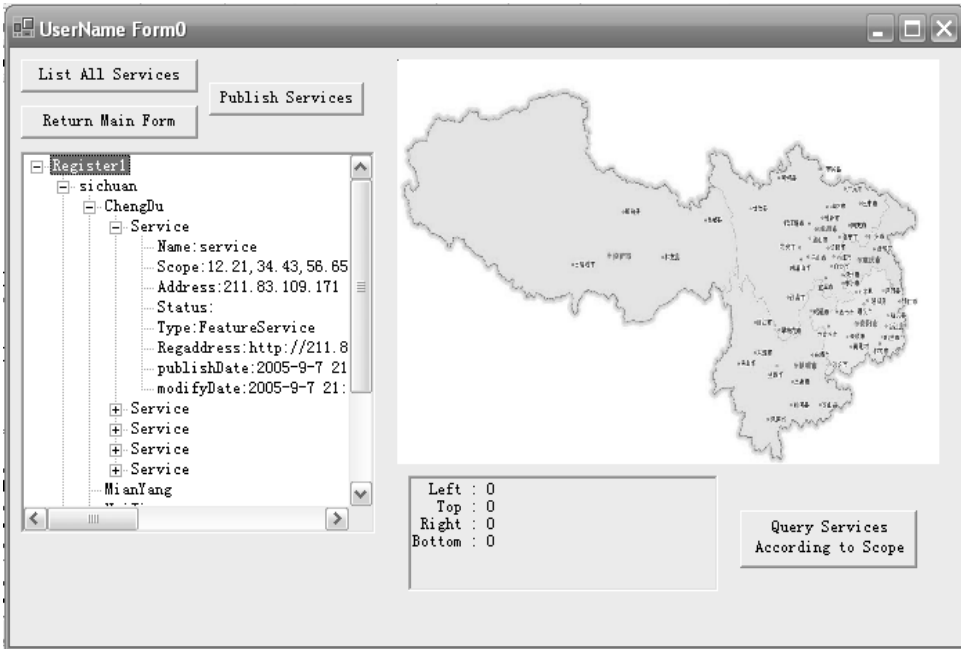


Fig. 10. The interface of the register service

### 3.2. The system Grid Services.

The resource management service is in charge of registering spatial information services and spatial data services to the registry center, and managing the services. The registry center is divided into three levels that constitute a structure of an index tree. The structure of an index tree facilitates to register, discover, update, and dispose the register information. The root node is the main register center, which is the first level register center. Resources are registered in the leaf nodes, and the junior register centers are registered in other nodes. The user interface of the register service is showed in Fig. 10. A user can list all services registered in the register center, and then select the service.

The monitoring service monitors the status of Grid nodes and GIS processing services. If the status of the registered service is changed, the monitoring service notifies the registry service to update the status. The method can ensure that the services in registry centers are exact and real-time.

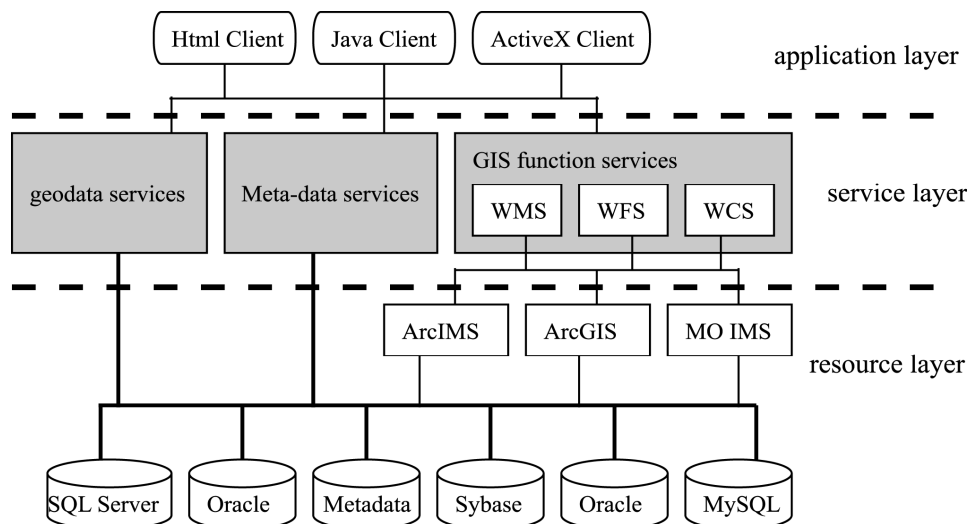


Fig. 11. The special Grid Services architecture

The security service is in charge of the security of the sharing platform. It provides two aspects security: one is access control service, which ensures that unlawful users can not access the resources in the sharing platform; the other is communication security service, which encrypts and decrypts transmitted data and implements digital signature.

### 3.3. The special Grid services.

The special Grid Services include geodata services, meta-data services and GIS processing services (as illustrated in Fig. 11 ). The geodata services access heterogeneous distributed database, and implement the geodata and meta-data sharing. The GIS function services invoke OGC-compliant services, such as Web Map Service, Web Feature Service, and Web Coverage Service, and share the Internet Map Services that run in distributed grid node. The meta-data services, as an assistance of geodata services, publish, find and manage meta-data.

## 4. Framework of the resource and environment Geo-information sharing Grid architecture based on Mobile Agent

According to the system principle, an application flow whose purpose is to query spatial data information in grid environment is put forth, as illustrated in Fig. 12.

- 1) A spatial data request is sent by the user who visits any site in the system via web explorer.
- 2) Web explorer and Aglets system are equipped on the web server. When a request for spatial data is accepted by a web explorer, a User Agent's agent is started by servlet engine to judge whether it is a native work. The reason that a User Agent is not started directly is that User Agent doesn't allow the outside to access and read its information directly but allows that via an agent which offers corresponding interface.

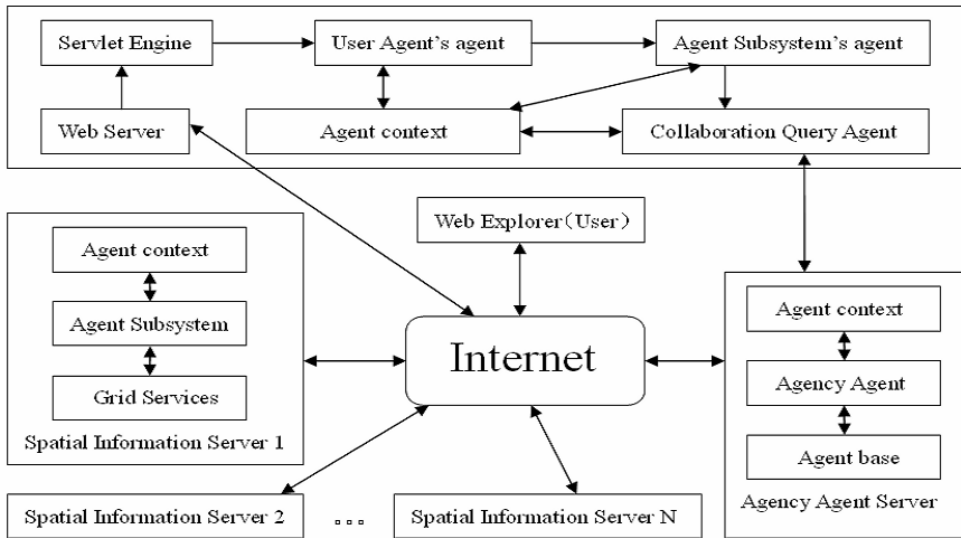


Fig. 12. The framework of Geo-information sharing Grid based on Mobile Agent

- 3) If it is a native task, a native agent subsystem's agent is started directly and dispatched to native spatial information server. When arrived, the native agent subsystem's agent sends a service request to spatial data service which is built up in Globus Toolkits 4 and returns the result to web server.
- 4) If it isn't a native task, a Collaboration Query Agent is created and dispatched to Agency Agent server, and then asks for querying spatial information servers. When obtains target spatial information server's address and port, web server starts proper agent subsystem's agent and dispatches it to target spatial information server. The agent communicates with spatial data service which is built up in Globus Toolkits 4 and returns the result to web server.
- 5) While getting all the information needed, the web server returns it to user via web explorer.

## 5. Conclusions

This Geo-information sharing platform provides integrated spatial information and applications for users with the technology of Spatial Information Grid, the Grid platform of OGSINET, and mobile agent. In this platform, a feasible method for spatial data sharing and interoperability in grid environment is provided. It makes data accessing easier and shields spatial data's heterogeneity. Users can access spatial information resource through uniform interface.

The interoperation of heterogeneous GIS is implemented in the Resource and Environment Geo-information Sharing Architecture for the Southwestern China. Via uniform user interface, web users can take advantage of geo-data and function provided by various Web GISs. However, there are some problems that ought to be further solved, such as the security of the access to spatial databases, the management of the Geo-information service lifecycle, and etc.

## 6. Acknowledgments

This research was funded partly by the National Basic Research Program of China (also called the 973 program, contract 2007CB714400), by National Key Technology Support Program (contract 2006BAJ09B09), and by Open Research Fund Program (contract GCWD200706) of Key Laboratory of Digital Mapping and Land Information Application Engineering, State Bureau of Surveying and Mapping ". The authors would also like to thank everyone who has supported this effort through his thoughtful discussions of issues raised in this paper.

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# Realization of lowpass and bandpass leapfrog filters using OAs and CCCII<sup>s</sup>\*

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## Abstract

The systematic procedure for realizing lowpass and bandpass leapfrog ladder filters using only active elements is presented. The proposed architecture is composed of only two fundamental active building blocks, i.e., an operational amplifier(OA) and a Current Controlled Conveyor II (CCCII), without external passive element requirement, making the approach conveniently for further integrated circuit implementation with systematic design and dense layout. The characteristic of the current transfer function can be adjusted by varying the external bias currents of CCCIIs. As illustrations to demonstrate the systematic realization of current-mode ladder filters, a 3rd-order Butterworth low-pass filter and a 6th-order Chebyshev bandpass filter are designed and simulated using PSPICE.

**Keywords:** operational amplifier (OA); current controlled conveyor II (CCCII); leapfrog filters; ladder structure; active-only circuits

EEACC: 1270

CLC number: TN713    Document code: A

## 1. Introduction

Analog designs have been viewed as a voltage-dominated form of signal processing for a long time. However in the last decade current-mode signal-processing circuits have been demonstrated and well appreciated over their voltage-mode counterparts due to the main featuring of wide bandwidth capability. Designs for active filter circuits using high performance active devices, such as, operational amplifier(OA), operational transconductance amplifier(OTA), second generation current conveyor(CCII) and so on, have been discussed previously<sup>[1-2]</sup>. Due to the fact that active filter designs utilizing the

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\* Project supported by the Natural Science Foundation of Hunan Province (NO. 06JJ50117)  
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finite and complex gain nature of an internally compensated type operational amplifier are suitable for integrated circuit(IC) fabrication and high frequency operation. Several implementations in continuous-time filters using only active components are recently available in the literature<sup>[3-6]</sup>. They have been demonstrated that the realizations of the resistor-less and capacitor-less active-only circuit would be attractive for simplicity, integratability, programmability and wide frequency range of operation. However, a design approach with only active architectures that are efficient for systematic design and very large scale integration(VLSI) has not been reported sufficiently.

The paper deals with the alternative systematic approach that has been used the leapfrog structure to obtain current-mode ladder active filters with the employment of all-active elements. The proposed design approach is quite simple and systematic which has no passive element requirements. The basic building blocks of all circuits mainly consist of OA and CCCII. The obtained feature of the filter constructed in this way is a general structure and is able to adjust the characteristic of the current transfer function by electronic means. Owing to all-resulting circuits are implemented such a way that employs only active-element sub-circuits and minimizes the number of different fundamental building blocks. It is not only easy to construct from readily available IC type, but also significantly simplified in the IC design and layout. As examples to illustrate that the approach considerably simplifies for the current-mode ladder filter realizations, the leapfrog-based simulation of a 3rd-order Butterworth lowpass and a 6th-order Chebyshev bandpass filters are designed.

## 2. Basic active building blocks

### 2.1 Operational Amplifier(OA)

The first fundamental active device is to be an internally compensated type operational amplifier(OA) as shown with its symbolic representation in Fig. 1. As is known in practice, the open-loop amplifiers have a finite frequency-dependent gain. If  $\omega_a$  is the -3dB bandwidth and by considering for the frequencies  $\omega \gg \omega_a$ , the open-loop voltage gain  $A(s)$  of an OA will be henceforth characterized by

$$A(s) = \frac{A_0 \omega_a}{s + \omega_a} \cong \frac{B}{s} \quad (1)$$

where  $B$  denotes the gain-bandwidth product(GBP) in radian per second, which is the product of the open-loop DC gain  $A_0$  and the -3dB bandwidth  $\omega_a$

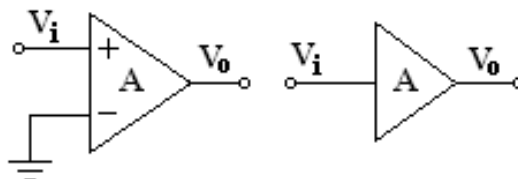


Fig. 1. Symbol of an OA

## 2.2 Current Controlled Conveyor II (CCCII)

A CCCII is a three-port active element. The port relations of a CCCII is shown in Fig. 2, characterized by the relationship

$$\begin{bmatrix} i_y \\ v_x \\ i_z \end{bmatrix} = \begin{bmatrix} 0 & 0 & 0 \\ 1 & R_x & 0 \\ 0 & \pm 1 & 0 \end{bmatrix} \begin{bmatrix} v_y \\ i_x \\ v_z \end{bmatrix} \quad (2)$$

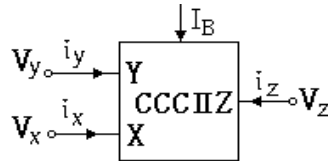


Fig. 2. Electric symbol of CCCII

The positive and the negative sign are corresponding to the CCCII+ and CCCII- respectively, and  $R_x$  is input resistance at port X. For the circuit of Fig. 2 the parasitic resistance, can be expressed as

$$R_x = \frac{V_T}{2I_B} \quad (3)$$

Where  $V_T$  is the thermal voltage  $V_T \approx 26$  mV at  $27^\circ\text{C}$  and  $I_B$  is the bias current of the CCCII. It is seen from equation (3) that the internal resistance  $R_x$  is adjustable electronically through the biasing current  $I_B$ .

## 3. Realization of lowpass and bandpass leapfrog ladder filters

Since the doubly terminated LC ladder network has been receiving considerable attention and popular due to it shares all the low sensitivity and low component spread of the RLC prototypes<sup>[7-12]</sup>. An systematic approach to realize current-mode ladder filters using only active elements is proposed. It is based on the leapfrog structure representation, which is derived from the passive RLC ladder prototypes. To demonstrate the proposed design approach, consider the general resistively terminated current-mode ladder filter with parallel impedances and series admittances shown in Fig. 3. The relations of the currents-voltages for the branches, the meshes and the nodes in this filter can be interrelated by

$$\begin{aligned} I_1 &= I_S - \frac{V_1}{R_S} - I_2, & V_1 &= I_1 Z_1 \\ I_2 &= V_2 Y_2, & V_2 &= V_1 - V_3 \\ I_3 &= I_2 - I_4, & V_3 &= I_3 Z_3, \\ \vdots &, & \vdots & \end{aligned}$$

$$\begin{aligned}
 I_j &= V_j Y_j & , & & V_j &= V_{j-1} - V_{j+1} \\
 I_i &= I_{i-1} - I_{i+1} & , & & V_i &= Z_i I_i \\
 & \vdots & & & & \vdots \\
 I_{n-1} &= V_{n-1} Y_{n-1} & , & & V_{n-1} &= V_{n-2} - V_n
 \end{aligned}$$

and

$$I_n = I_{n-1} - I_{n+1} \quad , \quad V_n = I_n Z_n \tag{4}$$

Where  $(i = 1,3,5,\dots,n)$  and  $(j = 2,4,6,\dots,n)$ . Equation (4) can be represented by leapfrog block diagram depicted in Fig. 4, where the output signal of each block is fed back to the summing point input of the preceding block. In contrast with the conventional simulation topology, however, we will present a simple, systematic and more efficient method unique to active-only current mode ladder filters by using the features of an OA and a CCCII.

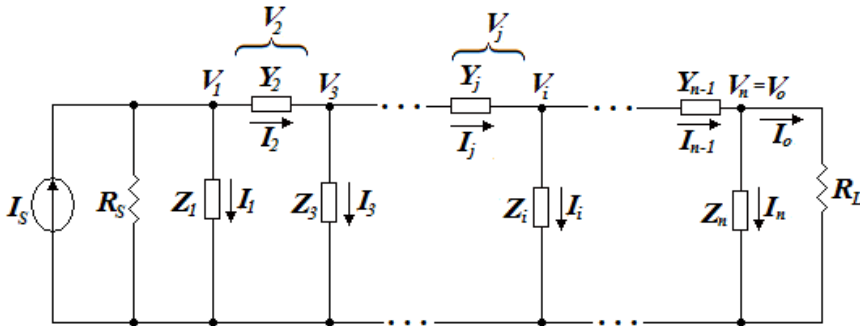


Fig. 3. General resistively terminated current-mode ladder prototype

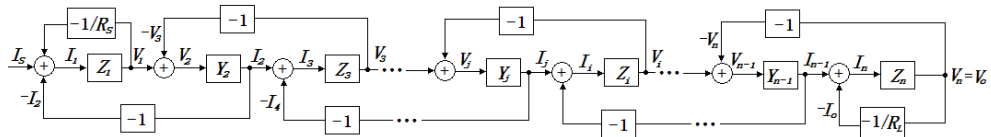


Fig. 4. Leapfrog block diagram of the general ladder prototype of Fig. 3

**3.1 Lowpass leapfrog realization**

As an example to illustrate the design procedure, consider the current-mode 3rd-order all-pole LC ladder lowpass prototype with regarding the terminating resistors shown in Fig. 5. The design techniques of these partial conversions can be accomplished in the way as shown in Fig. 6, through the use of only an OA and a CCCII as mentioned. Therefore, the circuit parameters have the typical values calculated by

$$R_{xi} = \frac{1}{B_i C_i} \quad \text{for } i = 1,3,5,7,\dots,n$$

and

$$R_{xj} = B_j L_j \quad \text{for } j = 2,4,6,8,\dots,n-1 \tag{5}$$

Where  $B_k(k=i \text{ or } j)$  represents the GBP of the  $k$ -th OA.

Based on the directed simulation of the LC branch as shown in Fig. 6, the system diagram thus straightforwardly derived from the passive RLC ladder circuit of Fig. 5 can be shown in Fig. 7. The design equations of the circuit parameters can be expressed as follows

$$\begin{aligned}
 R_x &= R = R_s = R_L \\
 R_{x1} &= \frac{1}{B_1 C_1} \\
 R_{x2} &= B_2 L_2 \\
 \text{and} \quad R_{x3} &= \frac{1}{B_3 C_3} \tag{6}
 \end{aligned}$$

Note that all elements, which simulate the behavior of capacitor and inductor, are tunable electronically through adjusting the resistor parameters,  $R_x$ .

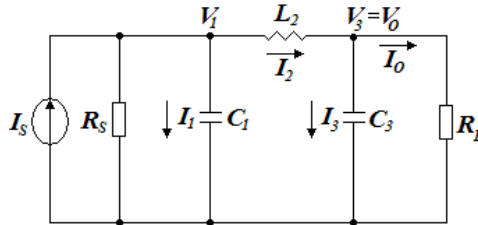
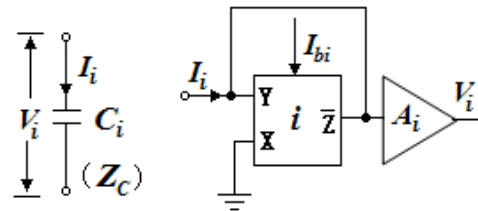
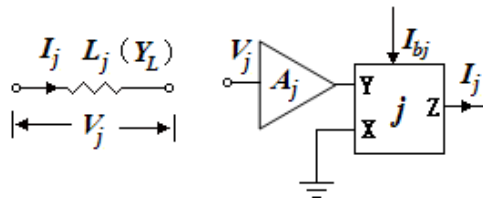


Fig. 5. 3rd-order all-pole LC ladder lowpass prototype



$$V_i = Z_C I_i \quad R_{xi} = \frac{1}{B_i C_i}$$

(a) parallel branch impedance



$$I_j = Y_L V_j \quad R_{xj} = B_j L_j$$

(b) series branch admittance

Fig. 6. Partial branch simulations using OA and CCCII of the lowpass network of Fig. 5

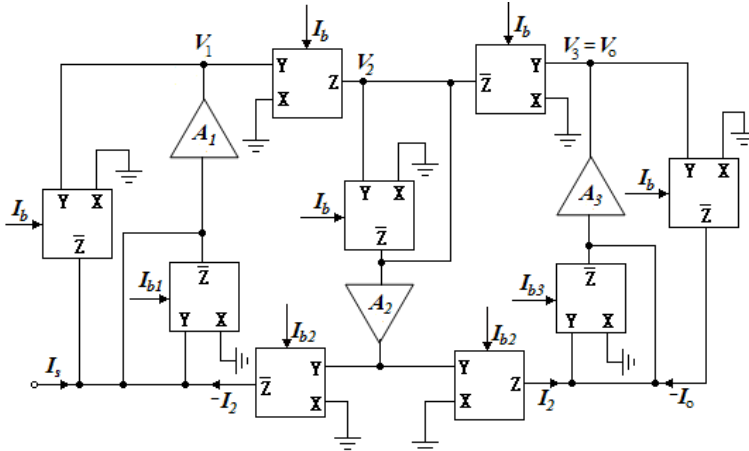


Fig. 7. Systematic diagram for current-mode 3rd-order lowpass filter using active-only elements

**3.2 Bandpass leapfrog realization**

The proposed approach can also be employed in the design of current-mode LC ladder bandpass filters. Consider the current-mode 6th-order LC ladder bandpass prototype shown in Fig. 8, having parallel resonators in parallel branches and series resonators in series branches. Observe that the repeated use of the bandpass LC structure branches typically consisting of parallel and series combinations of capacitor and inductor, shown respective in Figs.9(a) and 9(c), makes up the complete circuit. The voltage-current characteristic of these partial operations can be derived respectively as follows

$$V_i = Z_C(I_i - Y_L V_i) = \frac{1}{sC_i} (I_i - \frac{V_i}{sL_i}) \tag{7}$$

for  $i = 1,3,5,7,\dots,n$ .

$$I_j = Y_L(V_j - Z_C I_j) = \frac{1}{sL_j} (V_j - \frac{I_j}{sC_j}) \tag{8}$$

for  $j = 2,4,6,8,\dots,n-1$ .

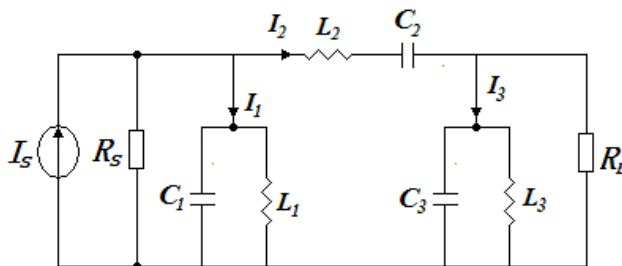


Fig. 8. 6th-order LC ladder bandpass prototype

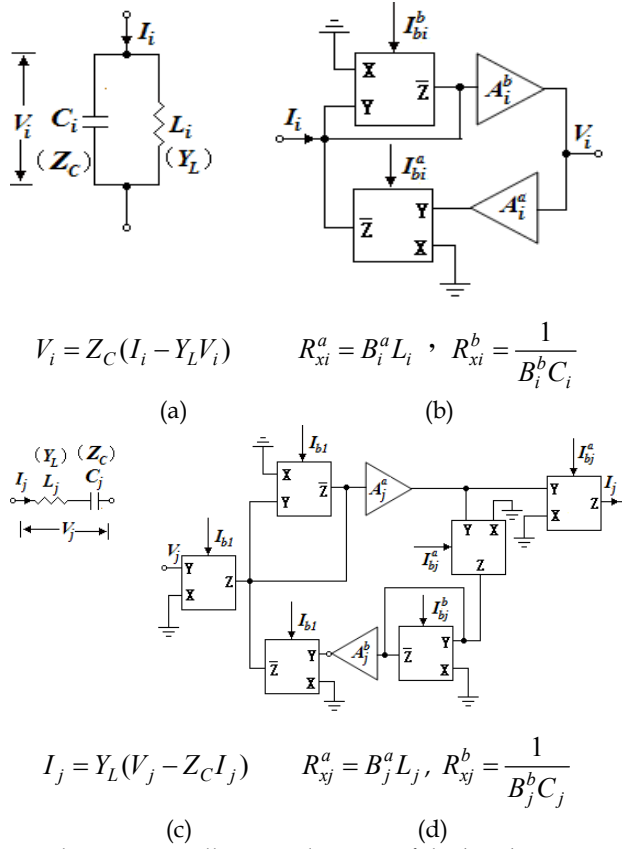


Fig. 9. Sub-circuit simulation using all-active elements of the bandpass network of Fig. 8

The resulting circuits for the active-only implementation of these structures corresponding to the sub-circuit operations of Fig. 9(a) and 9(c) are then resulted in Figs.9(b) and 9(d), respectively. The design formulas for the circuit parameters of each branch can be summarized below

$$R_x = R_s = R_L = R$$

$$R_{xi}^a = B_i^a L_i, \quad R_{xi}^b = \frac{1}{B_i^b C_i}$$

and

$$R_{xj}^a = B_j^a L_j, \quad R_{xj}^b = \frac{1}{B_j^b C_j} \quad (9)$$

The structure realization diagram of the bandpass filter, thus obtained by directly replacing each sub-circuit from Fig. 9 into the ladder bandpass prototype of Fig. 8, can be shown in Fig. 10.

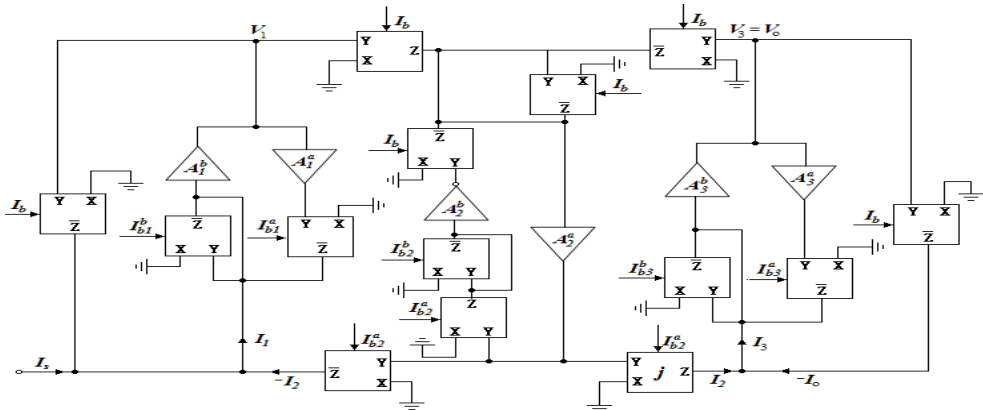


Fig. 10. Systematic diagram for current-mode 6th-order bandpass filter using active-only elements

Since all circuit parameters depend on  $R_x$  the values, a property of the proposed filter implementations is, therefore, possible to tune the characteristic of the current transfer function proportional to external or on-chip controlled internal resistance  $R_x$ . It is shown that for the employment of all active elements, a further advantage is to allow integration in monolithic as well as in VLSI fabrication techniques.

#### 4. Simulation results

To demonstrate the performance of the proposed ladder filter, a design of current-mode 3rd-order Butterworth lowpass filter of Fig. 7 with a cut-off frequency of  $f_c=100\text{kHz}$  was realized. This condition leads to the component values chosen as follows,  $R_x=1\text{ k}\Omega$ ,  $R_{x1}=R_{x3}=106.5\ \Omega$ ,  $R_{x2}=18.87\ \text{k}\Omega$ . The simulated result shown in Fig. 11 exhibits reasonably close agreement with the theoretical value. For another illustration a sixth-order Chebyshev bandpass filter response of Fig. 10 is also designed with the following specifications: center frequency = 50kHz, bandwidth = 1.0 and ripple width = 0.5dB. The approximation of this filter resulted in the following components values:

$R_x=1\ \text{k}\Omega$ ,  $R_{x1}^a=R_{x3}^a=11.765\ \text{k}\Omega$ ,  $R_{x1}^b=R_{x3}^b=33.33\ \Omega$ ,  $R_{x2}^a=20.62\ \text{k}\Omega$ ,  $R_{x2}^b=58.41\ \Omega$ . The simulated response of the designed filter verifying the theoretical value is shown in Fig. 12. In these simulations, The implementations of  $0.25\mu\text{m}$  CMOS OAs,  $0.25\mu\text{m}$  CMOS CCCII and their aspect ratio with  $\pm 2$  volts power supplies are illustrated in Fig. 13 and Fig. 14, respectively<sup>[13-14]</sup>. The W/L parameters of MOS transistors are given in Table 2 and 3, respectively. The CMOS OAs using  $C_1=30\ \text{pF}$  with bias voltage  $V_{B1}$  and  $V_{B2}$  set to -1V and -2V, respectively.



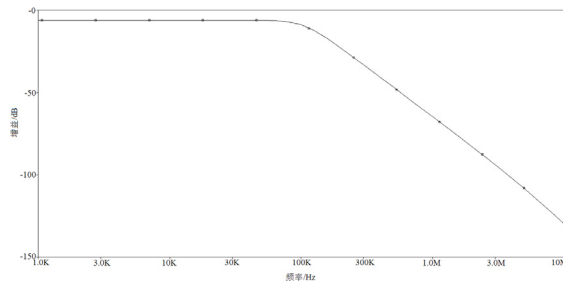


Fig. 11. Simulated frequency response of Fig. 7

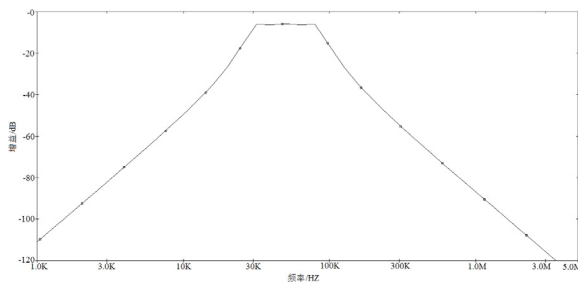


Fig. 12. Simulated frequency response of Fig. 10

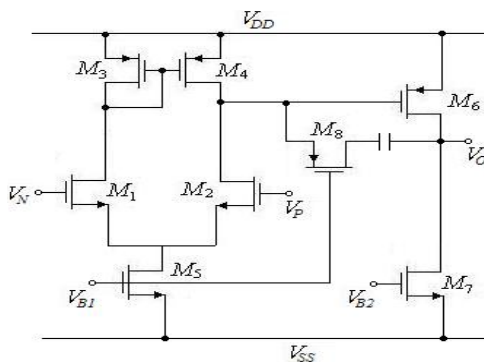


Fig. 13. CMOS OA implementation

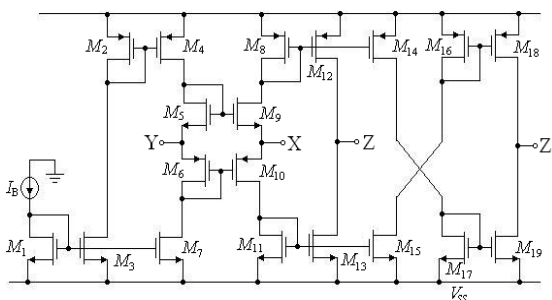


Fig. 14. CMOS CCCII implementation

Transistor	W ( $\mu\text{m}$ )	L ( $\mu\text{m}$ )	Transistor	W ( $\mu\text{m}$ )	L ( $\mu\text{m}$ )
M <sub>1</sub> , M <sub>2</sub>	250	3	M <sub>6</sub>	392	1
M <sub>3</sub> , M <sub>4</sub>	100	3	M <sub>7</sub>	232	3
M <sub>5</sub>	80	32	M <sub>8</sub>	39	1

Table 2. Transistors aspect ratio of COMS OA

Transistors	W( $\mu\text{m}$ )	L( $\mu\text{m}$ )
M <sub>1</sub> , M <sub>3</sub> , M <sub>7</sub> , M <sub>11</sub> , M <sub>13</sub> , M <sub>15</sub> , M <sub>17</sub> , M <sub>19</sub>	5	0.5
M <sub>2</sub> , M <sub>4</sub> , M <sub>12</sub> , M <sub>14</sub> , M <sub>16</sub> , M <sub>18</sub>	15	0.5
M <sub>8</sub>	14.2	0.5
M <sub>5</sub> , M <sub>9</sub>	2	0.5
M <sub>6</sub> , M <sub>10</sub>	4	0.5

Table 3. Transistors aspect ratio of COMS CCCII

## 5. Conclusion

This paper presented an alternative systematic approach for realizing active-only current-mode ladder filters based on the leapfrog structure of passive RLC ladder prototypes. The proposed design approach are realizable with only two fundamental building blocks, i.e., OA and CCCII, which does not require any external passive elements. A property of this approach is the possibility of tuning the current transfer function by the controlled resistance  $R_x$ . Because of their active-only nature, the approach allows to realize filtering functions which are suitable for implementing in monolithic integrated form in both bipolar and CMOS technologies as well as in VLSI fabrication techniques. Since the synthesis technique utilizes an internally compensated pole of an OA, it is also suitable for high frequency operation. The fact that simulation results are in close agreement with the theoretical prediction verified the usefulness of the proposed design approach in current-mode operations.

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