24/7 Software Development in Virtual Student Exchange Groups: Redefining the Work and Study Week

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Abstract - ***A concept of time zone driven, 24/7-week software development in a Virtual Student Exchange (VSX) environment is being defined, developed and applied to explore reliable and efficient continuous modes of work/study processes. The overall goal is to assess the suitability and benefits of this innovative approach to teaching and learning in order to increase the efficiency and effectiveness of these processes.***

This new methodology aims to address industry needs for training in international teaming, to enrich students' experience, and to improve the quality of education in the participating institutions. The techniques and tools discussed here create an integrated framework for international collaboration among teaming groups of students in practice and team oriented engineering education. This paper also aims to justify the need, merits, and feasibility of the virtual collaboration student exchange teaching program between educational institutions separated by three 8-hour time zones: the Faculty of Electronic Engineering of the Wroclaw University of Technology in Poland (WUT), the Faculty of Electrical and Computer Engineering at the University of Arizona, Tucson, USA (UA) and the Faculty of Engineering, Software Engineering Group at University of Technology, Sydney, Australia (UTS). The paper defines the proposed methodology, reviews the tools and processes involved, and finally reports preliminary results.

Keywords: **Teaching and Learning (T&L), 24/7 Virtual Student Exchange (24/7 VSX), Telecollaboration (TC), Software Development Life Cycle (SDLC)**

1. INTRODUCTION

At 03:11am my phone rings at home. At that hour of the morning we all expect that the caller may be a close family member requiring help to get to the emergency room in a hospital, or even worse - there's something terrible happening, a horrific disaster occurred in our neighborhood - the tunnel under construction is about to collapse and we are all required to evacuate from our homes … "It's your friend Dick - for you …" my wife says in an irritated voice. "I tried to contact *Dr Smith* and it went straight to the recording machine so I had no choice but to call you. Sorry to bother you, but I need your help with the modification in that code… By the way, what time is it in Australia now?". The voice was apologetic, yet my sleep was disturbed and the rest of the day was rather tiring.

The world's economy is becoming increasingly interdependent. For many countries the export account figures indicate a growing percentage of jobs, economic activity, and investment capital moving rapidly and frequently from one country to another [24]. At the same time we observe accelerating trends towards corporate internationalization and globalisation. Concurrently, over the last decade we are witnessing fairly dramatic changes in the study and work patterns occurring in the engineering profession environments [2, 22, 24, 26]. Recent rapid advances in information and communication technologies as well as a variety of new consumer products and services are reinforcing this process.

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A general tendency for specialised, autonomous, and collaborative teams in a traditional software [15, 17, 18] engineering practice has evolved and expanded into an international arena of telecollaborative (TC) [8, 9] engineering.

This recent orientation in engineering practices is supported by advances in the "next generation wireless" technology, the proliferation of ubiquitous devices, and the development of web based TC [9, 25, 28] software tools. These new trends combined with an expectation for constant access to services provided by knowledge workers (employees, teachers or students) are shaping a "New work order". To remain competitive in a global marketplace, future engineers need to posses team management skills in addition to being well trained in their field of expertise. They have to be well conversed in international business, being able to work in a geographically distributed environment and most importantly be trained in inter- and cross- cultural teaming [10, 11]. This last ability requires engineering adepts to possess effective work interaction skills and an awareness of cultural differences among different nations. It is expected that future engineers will need to be equipped with not only versatile technical skills and good knowledge of processes and technology, but will also need to possess multi-cultural and multi-lingual communication skills as well.

Since the beginning of 2006, three tertiary institutions (see the Figure 1) - the Faculty of Electronic Engineering of the Wroclaw, University of Technology in Poland (WUT), the Faculty of Electronic Computer Engineering at the University of Arizona (UA), Tucson, USA; and the Faculty of Engineering, Software Engineering Group at University of Technology, Sydney, Australia (UTS) have been working on a common framework and rules of engagement for a derivative of 24-Hour Knowledge Factory [14], a concept that we call the 24/7 Virtual Student Exchange (VSX) Teaching and Learning model. These 3 institutions are separated by 8hr time zones (or more) from each other.In the preliminary phase of the proposed 24/7 Virtual Student Exchange (VSX) initiative, participants need to examine how they can adapt, re-design and possibly match the structure of engineering subjects and educational programs currently taught at these three different tertiary institutions. The main aim here is to agree on common approaches, methods, project topics, lab tools as well as adopt a similar collaboration framework (processes) for a continuous work mode, project-based 7/24 VSX international educational model.

The other important aim is to provide an innovative and stimulating educational environment where students from diverse cultural backgrounds could practice

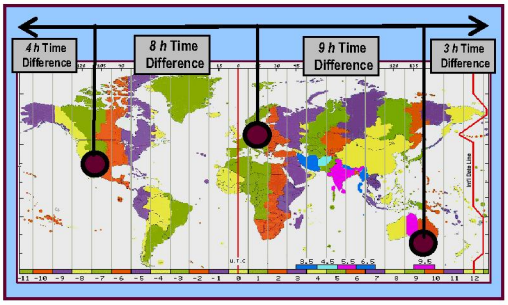

FIGURE 1. A MAP OF THREE (3) TELECOLLABORATING CENTERS TESTING THE 24/7 VSX MODEL

collaborative engineering skills at a global scale (in a virtual space).

An additional aim is to assess suitability, efficiency, effectiveness, and benefits of collaborative approaches in teaching and learning. Participants intend to explore, define, and apply various methodologies as well as collaboratively develop useful software applications/technologies in 3 centers separated by 8h time zones. Among the participating universities there are obvious differences in the curriculum of the engineering program as well as distinct approaches to teaching and learning. Hence, an agreement was reached that at the initial stage only the practice-based - software development and capstone project subjects would be used in the international collaborative teaming.

A sufficient level of synergy among participants can be achieved by adaptation of common engineering practices, subject quality evaluation criteria, and a student assessments framework [20, 21]. Integration and enhancement of selected subjects (or programs) by elements of collaborative international teamwork at partnering centers is achieved by leveraging technological advances.

The 24/7 VSX model of education has a great capacity to enrich a variety of subjects (even those perceived as highly "theoretical") by collaborative, participative, creative, cognitive, and emotive aspects of student teaching and learning. In fact, we are keen to see the 24/7 Virtual Student Exchange (VSX) model to be a real breakthrough in "collaborative engineering" education within a broader international and collaborative context.

Students in subjects adopting the 24/7 VSX model are instructed to study the problem space, create proper project management plans, perform detailed system analysis, and define system requirements in the context of collaborative international activities that are about to take place. Students are taught how to model business

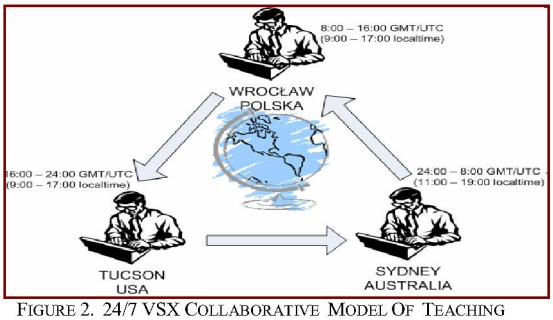

FIGURE 2. 24/7 VSX COLLABORATIVE MODEL OF TEACHING AND LEARNING . MODIFIED MODEL FROM A. GUPTA [14]

processes and architecture the software systems, so that various tasks could be divided in 3 different countries. A careful consideration is to be given to issues of what type of hardware; software programming tools and development platforms would be best suited for SDLC within the 24/7 VSX model. Worth noting is the fact, there is an absence of up-to-date quality measurements methods or tools, no Six Sigma, no process reengineering or integration standards. Educational institutions and the industry have not formally examined the flow of work required for the modern engineering industry in times of globalisation. There are no suitable benchmarks and often there is no proper accountability for the time and cost that various activities actually consume.

In the following sections, we introduce in greater detail the 24/7 VSX concept, its methodology, tools used, a case study, a review of work done so far, and provide some final observations. As it comes to training future engineering professionals, we are still pretty much relying on addressing dramatic changes to work patterns occurring in engineering professions. The novelty is the aspect of spatio-temporal continuity of the student project work within a framework that resembles the recent ideas of "24-7 Knowledge Factory" [14].

2. THE 24/7 VSX MODEL OF EDUCATION

At present, the only way for a student to gain experience in engineering collaboration and international teaming is to travel abroad for a period of time (for a semester or two).

Analysis of student attitudes supported by recent research studies [10, 11, 13] indicates that there are various other issues such as inflexibilities in curriculum, mismatched semester timing, financial limitations, family and friends; and just the sheer aspect of forward planning which discourage many students from pursuing study abroad. However, due to trends in the industry it is important that even students who have no motivation or desire to go abroad should have some effective exposure to aspects of international teaming [11] and inter-cultural collaboration [20, 24]. The key is to include an international collaboration and teaming experience in the undergraduate education programs in such a way that the disruption of their study programs would be minimal [12].

Currently, the only way that students can gain international teaming experience is by going abroad for a certain period of time. The concept of Virtual Student Exchange was originally developed and tested at the Northern Arizona University (NAU) as a mechanism for providing international teaming experience for most engineering undergraduate [11]. The overall idea was simple: to increasingly apply the same collaborative technologies that are being used in modern corporate environments and allow students in partnering universities to participate remotely in one another's subjects or courses.

The concept of 24/7 VSX describes an approach to teaching and learning where development of student projects or research is conducted in a telecollaborative mode [8, 9] in a globally distributed work environment (GDWE) [10, 11, 15] in which participants work on a project around the clock, each day of the week (24/7) [14]. In the GDWE environment project work is divided into manageable tasks that could be distributed among various teams working in 3 different time zones (as seen in Figure 2), located in different countries and on different continents. Each team member in a group works the standard workday hours. In 24/7 VSX students have an opportunity to practice and move closer towards the "24-hour global knowledge factory" concepts [14] where progress on engineering tasks is to be accomplished globally, on a round-the-clock basis.

Following the 24-hour global knowledge factory model, the 24-7 VSX project participants can increase their software team efficiency by having designing, coding, and testing done at different times of the day, so that work that would have been done over a period of three days can now be done within a 24 hour work cycle. Following the model it is feasible to complete a week's work within two (2) days and a month's work within a week. When working on projects in 24/7 VSX mode students need to realise the importance of considering the needs of various TC stakeholders at strategic, managerial, technical, economic, and social levels. Admittedly, there is a good chance that once students, educational institutions, various organizations, and enterprises adopt a common approach and train future knowledge workers to adopt the 24-hour knowledge factory concept [14], then we as participants would benefit.

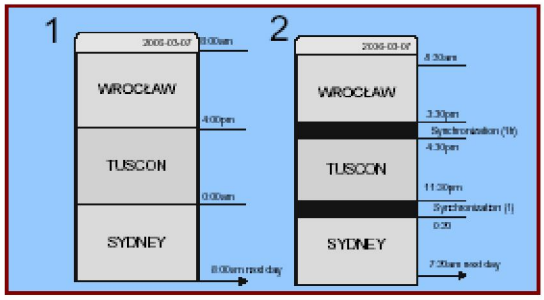

FIGURE 3. SYNCHRONISATION IN 24/7 VSX TEACHING AND LEARNING MODEL; 1-TRADITIONAL (NO SYNCH), 2- SYNCHRONISED

A globally distributed 24-hour call center is a classical example of this concept. The 24/7 VSX paradigm discussed in this paper involves student and university staff groups working together to complete a set of project deliverables (i.e. documentation, code, tests, demos, etc.) and transcending traditional spatio-temporal boundaries (8 hours) that pertain to her/his time zone. At the end of a workday, fellow team members located in a different time zone continue the same task or perform their own tasks depending on a selected mode. This creates a paradigm of a software development process in which shift-style knowledge workers create software in a continuous 24 hour cycle, working a most productive 8 hour day in a given time-zone, 7 days a week across the globe. The concept aims to harness difficulties with time, geographic isolation, and cultural differences between people by allowing joint international teaming of students at one institution to participate virtually in practice based, team-oriented subjects/courses offered at other institutions. Similar collaborative VSX initiatives (without the 24/7 component) have been practiced among American, German, and Polish universities [10, 11].

Encouraging results of these initiatives prompted authors of this paper to introduce and test yet another initiative around the 24/7 VSX model. It is expected that this innovative approach would allow students from three (3) different countries to practice telecollaborative teaming, thus not only enriching their separate educational programs but also offering a "real" experience in collaborative, international engineering in a global (virtual) work environment.

3. PROJECT MANAGEMENT IN 24/7 VSX

A continuous, 24 hour a day project development cycle demands dedicated management processes, which could cleverly interconnect despite being separated by time and space project development centers, so they appear as one integral organism. This approach has to ensure undisrupted workflow. Work in the 24/7 model requires management tools to provide support for a project organizational structure which may typically include such management layers as:

a) ***Project coordinator***(s) who is/are typically responsible for overall planning/scheduling, optimalisation of tasks, human resource management and support logistics. The project coordinator allocates resources and coordinates the work of development teams, test/integration teams, system administrators and configuration managers.

b) ***System administration team(s)*** who is/are responsible for all administration issues, hardware and software infrastructure support on the project. System administrators are responsible for the system and software back-ups, file recovery, as well as correct operation of software tools used on the projects.

c) ***Development team/test/integration teams*** are responsible for software requirements elicitations and analysis, architecture design, development, testing, resolution of problems and system integration. The teams should include system architects/chief designers, team leaders, and other similar technical functions. There is no need for a program administrator's role if advanced tools that support the 24/7 educational model are made readily available. Also, in all development centers there is no need for a uniform set of procedures and protocols as these may depend well on local socio-technical and cultural aspects as well as specific engineering practices.

3.1 WORK SYNCHRONISATION IN 24/7 VSX

Synchronisation of project tasks undertaken in distributed centers within 24/7 VSX program plays an extremely important role. As mentioned earlier the development work at each of the development centers is to be performed in dedicated time slots (or virtual shifts) that relate to standard day times pertinent to a given time zone (i.e. 9.00am to 5.00pm). Certain tasks often need to be continued and carefully passed on from one team to another. To avoid duplication of efforts or possibly making mistakes, this requires an overlap period or synchronisation time as depicted in Figure 3.

The proposed model requires a redefinition of traditional project management practices and processes. To be effective the model needs to be supported by advanced programmatic tools that could facilitate time management, task allocation, task execution, task transfer coordination and communication among collaborating team members in all distributed work centers. Such dedicated tools need to adjust and monitor work-time versus the current zone - time to meet requirements of all teams. One of the propositions was to use *Greenwich Mean Time (GMT)* as a project base-time (*BT*) for a

selected project admin tool commonly used in collaborating tertiary education institutions. The *BT time* will be used to express the internal body clock and hours of the project(s). Any task allocation, transaction or operation performed on the project has to be time-stamped or measured using *BT* time.

3.2 Software Development Process Methods

Software processes and development work involved in subjects adopting the 24/7 VSX model of teaching and learning can pose a real challenge in diversified and distributed educational environments [17, 19]. One of the simplest methods of organising software development on large-scale student projects [2, 7, 12] that can be effectively used in the 24/7 VSX model and which appears to be relatively easy to adopt considers independent development of separate software modules at each of the independent centers. Collaboration using the "modular method" is practically limited to an exchange of implemented modules (packages) between teams and then their integration in all or in selected centers. Various project tasks, often duplicated would be independently executed at each of the centers separately as shown in Figure 4. This method is suitable in cases when each of the centers has a sufficient resource of highly specialised managers, developers, and testers. At some stage however, software integration in this method could pose serious issues.

Another possible method of telecollaboration [9] is to organize development work in continuous, task sharing mode, using uniform development teams with similar task allocation and responsibilities. In this mode, work on various software modules/subsystems is shared between teams in separate centers as depicted in Figure 5. Following this method, developers are able to continue development tasks when these are passed on to them from another center. A completion of a software module is the result of efforts of all development centers involved. It is hard to foresee all of the possible problems

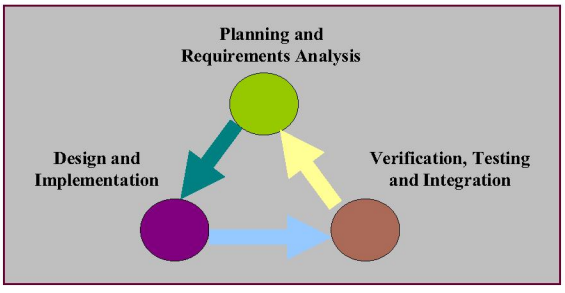

FIGURE 4. MODULAR APPROACH TO SOFTWARE DEVELOPMENT IN 24/7 VSX TEACHING AND LEARNING MODEL

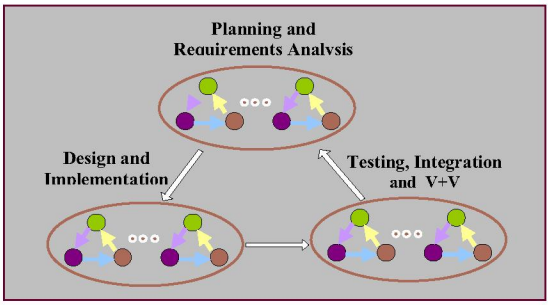

FIGURE 5. CONTINUOUS WORK-FLOW SOFTWARE PROCESS APPROACH IN 24/7 VSX EDUCATIONAL MODEL

that may occur might be appropriate division of work packages/modules across all centers work. Developers commencing work at a given center continue a task(s) started by their predecessors. To ensure a smooth 24 hour workflow this method requires a more disciplined approach with proper communication, coordination, and documentation of work/tasks executed in each of the centers. Difficulties may appear in definition and sizing of work-packages that would be suitable for software processes within the 24/7 VSX model. Hybrid methods, that may combine both approaches, can be considered as well. All of the methods discussed can allow application of iterative, spiral process software development methods in all centers.

The modular approach focuses on an optimal usage of time, tools, and human resources on one project. The "task sharing", continuous workflow method requires adequate work synchronisation where an arbitrary synchronisation period may vary from 1 to 0.5 hour between each shift. A synchronisation period can overlap over the last and first half hours of a shift. There are certain risks and additional requirements related to this mode of operation. For example, it is difficult to allocate identical levels of human resources with similar expertise or to ensure similar levels of performance at each of the three (3) development centers. Also, due to other study commitments students may not be able to strictly adhere to continuous 24/7 shift-style work. Hence, a possible compromise might be to divide the work week into three 2-days shifts, which is more likely to guarantee that each student group will fit into 24/7 workflow.

4. Review of Collaborative Engineering Tools For 24/7 VSX

Recently, much research interest has been shown in the development of tools specifically designed to meet the needs and challenges of group-work and TC applications.

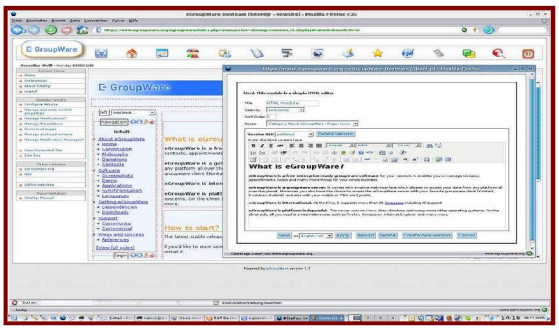

FIGURE 6. SITEMGR CMS TOOL USED IN 24/7 VSX [30]

These research activities are focusing on the work-group project management and planning, configuration control, and file (resource) sharing. There is a shortage of development tools suitable to support continuous workflow along the 24/7 VSX model lines. Such collaborative engineering tools should allow developers to share common resources while documenting, coding, testing, or integrating. Two similar projects, *Pavilion* and *Tango* [9] that attempted to build collaborative engineering tools resulted in the development of a Web-based collaborative framework. The aim of the *Pavilion* project was to build a proxy-based, object-oriented software integrating infrastructure supporting software reuse, extensibility, interoperability, and maintenance.

The project introduced a range of host-level integration techniques to support workgroup communication, event synchronization, and management control. TC applications developed on the project were sensitive to the heterogeneous characteristics of the computing devices and the network connections used by the participants. In the *Tango* project, collaborative *CollabWorx* tools [29] share the file and project states using an event-sharing mechanism. Events are shared via a TI plug-in layer and a dedicated real-time messaging server - TI Meeting Engine (*TIME*). The idea behind this method is for collaborative tools to use middleware services for communication between various client services.

For development our collaborating centers initially adopted open source e-groupware solution [30], which offers a set of collaborative tools to facilitate project management, source control, and communication among several groups of developers. At the initial stage centers agreed on using the e-groupware from (see Figure 6) as being able to adequately support project development using the modular (batch) development process.

There is still a shortage of useful tools that would support the continuous cycle of software development in a distributed environment with work patterns pertinent to the 3-time zones 24/7 VSX model.

5. THE CASE STUDY – SMART SHOP SYSTEM

Among the 24/7 VSX project participants a consensus was reached to explore the embedded wireless sensor networks (WSN) and RFID technologies in a development of Smart Shop System (3S) application. The choice of WSN based technologies provided a rich and challenging scope for exploration of important design and algorithmic problems. In the first semester of the 24/7 VSX project, students followed the modular method of work organization. In three development centers, students first concentrated on project managerial issues, initial planning, collaborative framework, studying/work methodologies, exploring collaborative engineering, and software development tools. Soon after, this was followed by an initial system of software analysis and preliminary design. Progress was made by all teams in adaptation and development of prototype tools for collaborative engineering environment.

There have been serious efforts made to develop smart algorithms that can be applied in the WSN-based 3S system. Student development teams explored and provided interesting solutions to increase a WSN-based system's fault tolerance, robustness, safety and security.

5.1 WORK IN PROGRESS

System Analysis and Requirements Definition.
In the system analysis phase of the projects students attempted to scope the problem space, derive initial system requirements, and provide possible architectural blueprints. The initial system (core) requirements for the 3S system included the following features:

- The RFID based tagging functionality to assist with stocktaking and inventory control
- The functionality to determine and monitor buying patterns of customers, and co-relate these patterns with store layout and planning. This function should assist in business decision to place popular products at more prominent positions for greater sales opportunities, etc. This function should also allow to help in establishing marketing scheme of business
- The functionality to monitor the placement of various good and products- this is required for both for security and to trace movement of stock (misplacing stock outside the store's boundary) purposes
- The Inventory Stock-take functions to find missing stock to reduce erroneous stock-check (i.e. Stock finder will identify stock not in its correct location)
- e-Retail function components using web technologies Integration facility with current legacy systems through modular and flexible system architecture

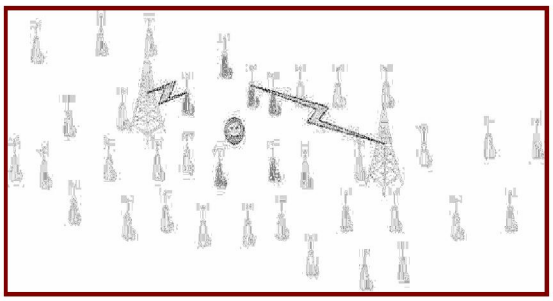

FIGURE 7. SENDING INFORMATION TO CLUSTER HEAD AFTER REACHING BYZANTINE AGREEMENT

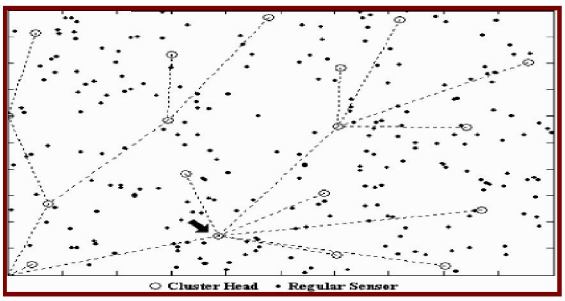

FIGURE. 8. CONNECTIONS IN CLUSTER HEAD LAYER WITH SINK AT (0,0) SIMULATION. 'POPULAR' CLUSTER HEAD IS POINTED OUT

- Users need to be able to integrate into an existing Apparel 21 POS and inventory management system
- Integration facility with a deployment of company-wide CRM.
- Automatic Fitting Room integration

Development of Algorithms and Simulation.
Students explored and studied various derivatives of sensors' energy saving routing protocols, Byzantine Failure Tolerance [17] algorithms (shown in Figure 6), Neural Networks, Artificial Immune Systems, and other algorithms that can be used in fault-tolerant, WSN-based systems. The smartness of the 3S system can be achieved through replication of services (algorithmic computations) in various components of the WSN-based system. The aim was to implement an evolving system that can operate in a reasonably correct manner even in presence of unexpected events, local faults or issues related to the sensor's batteries. In distributed systems similar to WSN - local system problems can be resolved locally without involving the rest of the infrastructure. In a 3S infrastructure, sensors are left unattended and they form a dynamic network. One of the challenges students attempted to explore was to increase network operation lifetime. At first, a solution for clustering protocols in setting up communication routes between cluster heads in WSN was provided. Then effective routing algorithms and topologies that increase sensors' lifetime, improve system's security and robustness were implemented and tested (as seen in Figure 7).

6. ADVANTAGES OF 24/7 VSX

There are many advantages in using the 24/7 VSX project management methodology in teaching project based software development subjects. Apart from creating a real collaborative workflow environment in which students can practice cross-cultural communication and enhance software development skills required in a global enterprise, it also helps to reinforce and enrich educational processes. The technique promotes collaboration between universities and helps to facilitate the exchange of various educational ideas. Methodology requires from students discipline, adequate planning, proper task scheduling, and adherence to delivery deadlines. If correctly managed the methodology.

7. CONCLUSION

The 21st century engineers, in addition to traditional technical skills, will be required to perform multiple roles (e.g. developer, project manager, cultural mediator) in variable size, often within autonomous and independent international design teams; for this they will need solid communication and teaming skills and as failure of one of them to deliver on time may not necessarily cause a break-down of the whole project as another group can take over and can still complete a task on time. Engineering groups can work in their most productive natural biological life cycle. Some disadvantages of the methodology relate to additional time that is required for work synchronisation and communication among spatio-temporal separated groups. Also, team members in various groups may not have the opportunity to physically interact with each other must be prepared to efficiently work with teams from other linguistic and cultural backgrounds. The concept of the 24/7 VSX provides a mechanism for training students to meet these challenges without need for students to visit foreign territories. Tertiary institutions should seriously consider training students for international collaborative work. TC initiatives between universities from different countries along the 24/7 VSX model can be very effective and realistic. With few costs and minimal risks, the method allows exploration of various scenarios of future training for engineers for the reality of work with potential clients across the globe. To facilitate this approach, participating institutions need to cross-pollinate compatible methodologies, subjects and courses so the teaching and learning telecollaboration techniques can be effective and beneficial to all parties. Telecollaborating staff and students across continents in different time/geographical zones can level out the

workload, share computer resources, balance access time burdens, and build contingency programs.

Additionally, the proposed continuous 24/7 VSX study method offers a unique experimentation platform that can be used for training students in 24/7 work patterns. Experimenting in an educational environment has its merits and there are pedagogical risks involved (i.e. subject's integrity, uniform assessment criteria, risk of failures, conflict of interests, etc.) [27]. Often however, negative experiences on student projects can be perceived as "lessons learned".

These are the early days for our three (3) groups; there are great challenges and there are still fundamental problems in the 24/7 VSX model that need to be addressed. The model's SDLC practices need to be redefined. For example, the new approach will introduce timing issues in a concurrent software development life-cycle(s). Without refining these ideas or attempts for standardization there are limited chances for wider acceptance of the model. Yet we remain optimistic, we maintain high expectations for future opportunities and positive outcomes of the 24/7 VSX model initiative.

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