Technological Developments in Education and Automation

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Editors

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Preface

This book includes the proceedings of the 2008 International Conference on Engineering Education, Instructional Technology, Assessment, and E-learning (EIAE 08) and International Conference on Industrial Electronics, Technology & Automation (IETA08). Both conferences were part of the International Joint Conferences on Computer, Information, and Systems Sciences, and Engineering (CISSE 08). The proceedings are a set of rigorously reviewed world-class manuscripts presenting recent technological developments in education and automation.

CISSE 08 was a high-caliber research conference that was conducted online. CISSE 08 received 948 paper submissions and the final program included 390 accepted papers from 77 countries, representing the six continents. Each paper received at least two reviews, and authors were required to address review comments prior to presentation and publication.

Conducting EIAE 08 online presented a number of unique advantages, as follows:

- All communications between the authors, reviewers, and conference organizing committee were done on line, which permitted a short six week period from the paper submission deadline to the beginning of the conference.
- PowerPoint presentations, final paper manuscripts were available to registrants for three weeks prior to the start of the conference.
- The conference platform allowed live presentations by several presenters from different locations, with the audio and PowerPoint transmitted to attendees throughout the Internet, even on dial up connections. Attendees were able to ask both audio and written questions in a chat room format, and presenters could mark up their slides as they deem fit.
- The live audio presentations were also recorded and distributed to participants along with the power points presentations and paper manuscripts within the conference DVD.

The conference organizers and us are confident that you will find the papers included in this volume interesting and useful. We believe that technology will continue to infuse education thus enriching the educational experience of both students and teachers.

Magued Iskander. PhD, PE
Vikram Kapila, PhD
Mohammad Karim, Ph.D.
June 2009

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Acknowledgements

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The excellent contributions of the authors made this world-class document possible. Each paper received two to four reviews. The reviewers worked tirelessly under a tight schedule and their important work is gratefully appreciated. In particular, we want to acknowledge the contributions of the technical committee members who provided the bulk of peer review.

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Performance-Based Measurement for Thai Educational Organization: A DEA Management Model

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Abstract- **This study employs the Data Envelopment Analysis (DEA) technique, an efficiency model, to measure public schools in Thailand. Data came from 455 public upper secondary schools in Northern Thailand. The results reveal that the schools mostly operate inefficiently. To ascertain the efficiency measures, sensitivity analysis reveals the robustness of the resulting efficiency measures on efficiency. Policy to improve school efficiency may thus consider using efficiency-based analysis for measuring school performance to identify which school will yield higher marginal returns to prioritize inefficient schools for treatment, in addition to allocating budget based on block grants or enrolments.**

I. Introduction

With the scope of unstoppable change under globalization age, governments in the Asia-Pacific region are finding it increasingly more difficult to put their educational policies into practices [[1], [2]]. Although spending on education is major government expenditure for the region's countries, the capacity of their educational systems to meet the new demands of this global age is still in question [3].

Thailand, one of the relatively fast-growing economies of Southeast Asia, has been providing the largest share of total public expenditure to education since 1991--even after the 1997 economic crisis began, the government provided 25% of total expenditures, or 4.3% of GDP, for education, which was a greater portion than before, demonstrating its commitment to education for the nation's recovery and development [4]. However, although the Thai government has committed significant resources, its degree of efficiency in providing educational services and procedures is still unclear [4].

This study employs a DEA technique to assess public general upper secondary school efficiency in Northern Thailand. DEA has been recognized as a useful management tool that can be applied for evaluating the relative efficiency of various organizations, e.g., hospitals [5], banks [6], or schools [7], as it compares a given unit to the best-performing units in its peer. The results obtained can identify relatively efficient/inefficient organizations and allow policy makers to develop performance-based policies to assist inefficient ones to improve their performance.

The purpose of this study is to estimate school efficiency and examines the robustness of resulting measures on efficiency by using sensitivity analysis. During the past decade, while most DEA studies have measured school efficiency in the U.S., U.K., Finland, Spain and Australia, very few studies have dealt with schools in Thailand. The novel methodological contribution of this study is a statistical foundation of output efficiencies along with a sensitivity analysis for the robustness on efficiency.

II. The Analytical Framework

The analytical framework of this study would entail: (1) measuring school efficiency, and (2) testing the robustness of resulting on efficiency measures.

The data envelopment analysis (DEA), an efficiency model initially introduced by [8], is used to assess school efficiency, through viewing schools as productive units using multiple inputs to generate multiple outputs. DEA is a deterministic means of constructing a "piece-wise linear" approximation to the frontier based on the available sample. In simple terms, the distribution of sample points is observed and a "kinked" line is constructed around the outside of them, "enveloping'' them (hence the term "data envelopment analysis"). DEA provides a comprehensive analysis of relative efficiency by evaluating each decision-making unit (DMU) and measuring its performance relative to an envelopment surface composed of other DMUs. Each DMU in a given set can then be ranked according to how efficiently it either utilizes its inputs to produce its outputs or it maximizes its outputs using its given inputs, depending on the measuring propose. Units that lie on the surface are deemed "efficient" in DEA terminology, while units that do not lie on the surface are termed "inefficient". The unit of measurement of DMU performance used is an efficiency score. After evaluation of the relative efficiency of the present set of units, the analysis shows how inputs and outputs have to be changed in order to maximize the efficiency of the target DMU. DEA also suggests a benchmark for each inefficient DMU at the level of its individual mix of inputs and outputs.

DEA has been used and cited as an important approach to assess school efficiency internationally [[7], [9], [10], [11],

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[12]] and has been proposed and assessed Thai school efficiency [[13], [14], [15], [16], [17]] due to its several unique advantages over other traditional techniques, e.g., ratio analysis and regression analysis [18], [19]]. First, DEA can handle multiple inputs and outputs on a simultaneous basis in the input/output education production function. Second, DEA does not require parametric specification of the production function in mathematical form. Third, DEA does not assume behavioral assumptions, e.g., like cost-minimizing or profit-seeking behavior, and this is especially relevant to public schools, which are non-profit organizations. Fourth, inputs and outputs that are contributing to inefficiency are identified and administrators can decide whether a reallocation of resources is necessary or feasible. Finally, managerial strategies for improvement of inefficient decision-making units can be determined.

In the context of public schools, [11] noted that an output maximization DEA model was more appropriate behavioral assumption to take than an input minimization one since school principals should be oriented towards obtaining the best results on the basis of the resources available to them, rather than minimizing these resources, over which they exercise no control –which is a philosophy that is implicit in the output orientation version. A number of studies including [[7], [9], [11], [13], [14], [17], [20], [21]] used the output-oriented approach for assessing school efficiency. The graphical illustration of output maximization DEA model is shown in Figure 1.

Figure 1 illustrates technical efficiency using the case of four schools, A, B, C and D, utilizing a single school input (x) to produce two outputs, y_1 and y_2. The best practice production frontier is defined by the schools that can maximize outputs for a given input. Schools C and D, in this example, are efficient because they lie on the best practice production frontier (isoquant G-G') and the value of the output distance function for each is equal to one. School A and B, which lie inside the frontier, are inefficient and each has an output distance (OA/OA′) and (OB/OB′) of less than one, respectively.

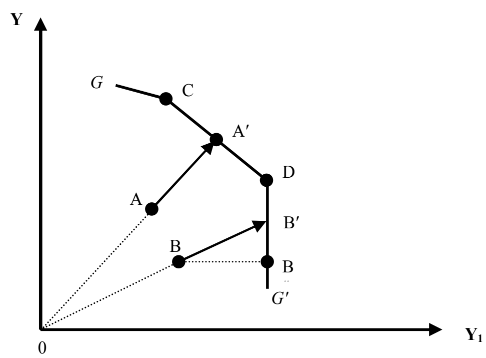

Fig. 1. Output-Oriented DEA Model

DEA technique can be carried out by solving an output-oriented linear programming, incorporating the assumption of constant returns to scale in the following equation [(Eq. (1)].

$$\text{maximize: } Z_0 = \phi_0 + \varepsilon \left[\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+ \right]$$

Subject to:

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^+ - y_{r0}\phi_0 = 0, \quad r = 1,\dots,s;$$

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^- - x_{i0} = 0, \quad i = 1,\dots,m;$$

$$s_i^- \geq 0;\ s_r^+ \geq 0;\ \lambda_j \geq 0 \qquad (1)$$

where x_{ij} and y_{rj} represent the observed values of the *i*th input and the *r*th output for school *j* (j = 1, …, n); λ_j is the input and output weights of other schools; s_i^- and s_r^+ are the slacks; ϕ_0 represents the efficiency of the school being evaluated; ε, a small positive constant, guarantees that inputs and outputs are positive and that the slacks do not influence the target function Z_0.

For assessing all schools in the sample, Eq. (1) is *n* times, giving *n* sets of λ_j, one set for each school, to determine its relative efficiency. In an output-oriented DEA model, technical efficiency is measured by the reciprocal of the output distance function [[20], [22]]. The reciprocal of the direct output function gives the proportion by which all outputs can be expanded, given the inputs. This output-oriented DEA model implies that the efficiency score (ϕ) will be equal to or higher than 1. An efficiency score (ϕ) of 1, together with nil values for all the slacks, indicates efficiency, i.e., that the school being evaluated has obtained the maximum possible production on the basis of the limited resources are available to it and the conditions under which it operates. A score of higher than 1 indicates that the school being evaluated could increase its production by the proportion (ϕ-1) without changing its current resources.

Sensitivity analysis was conducted to ascertain the robustness of the efficiency scores from the empirical findings. Two other input and output specifications are conducted to examine whether additional modifications in the educational production function could result in substantive changes in the empirical findings of efficiency measures. In addition to primal specification (Specification 1), one of output variables is decomposed into 3 sub-variables in Specification 2. In Specification 3, one input variable is added. Moreover, it is meaningful to note that there are several factors which may affect the stability of the efficiency results [[9], [10]]. First, the efficiency frontier may be partly based on outlier units or efficient schools that are very different from other units, either genuinely or due to miscoding, measurement error, etc. In such a case, omitting these outliers may change the mean efficiency and rankings based on efficiency scores. Second, the use of different combinations of inputs and outputs may change the ranking of individual schools. Thus, two forms of sensitivity analysis were conducted. First, a form of sensitivity analysis known as "jackknifing" is used to test the robustness of DEA results in regard to outlier schools. Second, Spearman rank correlation between DEA specifications was used to test the changes in their ranking based on efficiency score from one DEA specification to another.

III. DATA AND RESULTS

Data came from 455 public general upper secondary schools that were in Northern Thailand in 2003. All of these schools were under the same regulations of the Office of the Basic Education Commission (OBEC) of the MOE and utilized the same curriculum, thus ensuring homogeneity across the schools, and that all schools had the same production technology.

Inputs (X_i) used here are the teacher-student ratio [[7], [11], [13], [14]] and proportion of students not from low-income families [[9], [13], [14], [23], [24]], to reflect the quantity of resources available (e.g., teachers) and quality of inputs (e.g., students). This study includes SES input in DEA model since it has been argued that if SES was not included in calculating efficiency, the results obtained would not be operationally valid [25]. Because general upper secondary school lasts for three years, input data covers 2001-2003, measured as an average whenever possible. To measure school outputs (y_r), average national test scores [[7], [9], [10], [13], [14]], the number of students who passed their grades after first and second year (average of 2001-02) or were moved up [[10], [13], [14]], and number of graduates [[10], [13], [14]] were included to measure school efficiency. (A full list of descriptive statistics of input and output variables, together with description of variables, is provided in the Appendix.)

Applying the output-oriented DEA model in Equation 1 to each school in the sample yields descriptive statistics of the efficiency measures in Table 1. The average level of efficiency for the sample is 2.2618, indicating that, on average, all outputs being produced could be expanded by 126.18% (2.2618-1) at the given input usage. Variation of efficiency measures is 0.7373 when the gap between the maximum inefficiency measure and best practice is 4.6399 (5.6399-1). This suggests that although efficiency of schools in the set differ from each other by 0.7373 on average, the range between the least efficient and best practice schools in the pooled sample is as high as 4.6399 (5.6399-1). Further, only 4 schools were on the efficiency frontier (with efficiency score of 1). These results indicate that the schools under observation operate efficiently only 0.88% (4/455). In the other words, almost all schools operate inefficiently.

TABLE 1
EFFICIENCY RESULTS

Mean (S.D.)	Maximum Inefficiency Score	Maximum Efficiency Score	No. of Efficient Schools
2.2618 (0.7373)	5.6399	1.0000	4

At the individual school level, the efficiency measure indicates how much output could be proportionally expanded and using the same amount of inputs. For example, in Table 2 the efficiency score of school "Sh17" is 1.6633, implying that all outputs of this school could be expanded by 66.33 % (1.6633 – 1) using the same amount of inputs. In addition, setting adjustment targets for a given school needs to take into consideration that institution's input and output slack. Sh17 has output slack of 42.77 graduates. The output slack figures indicate the extent of further output augmentation after the expansion by 66.33%, while still maintaining the same input level.

On the input side, there is slack of 0.16 SES, representing the potential input reduction for the school even after its outputs have been adjusted for efficiency. Further, adjustment targets for school (Sh17) show that it's passing, graduates, and SAT scores can be raised by 483.55, 191.35, and 23.68 respectively. The SES of this institution can be reduced by 0.16. Slack in the SES index can reflect the school's relative ease of overcoming learning difficulty due to student SES. Similarly, the number of passing and graduates, and SAT of schools are also dependent on the SES.

TABLE 2
ADJUSTMENT TARGETS OF SCHOOL (SH17) IN THE SAMPLE

Variables	Existing Inputs And Outputs	Slacks	Adjustment Targets	Efficient Targets
Inputs				
Teacher-student ratio	3.42	0.00	0.00	3.42
SES	0.80	0.16	0.16	0.64
Outputs				
Passing	729.00	0.00	483.55	1,212.55
Graduates	224.00	42.77	191.35	415.35
SAT scores	35.70	0.00	23.68	59.38

Further, efficiency scores of schools in the sample were calculated using the output-oriented DEA model in Equation 1 together with the two additional specifications. Table 3 compares the efficiency scores of schools the primal specification (1) and the alternative specifications (2 and 3).

TABLE 3
DESCRIPTIVE STATISTICS OF EFFICIENCY SCORES, SPECIFICATIONS 1 – 3

Specification	Mean (S.D.)	Maximum of Inefficiency Score	No. of Efficient Schools	% of Efficient Schools
1*	2.2618 (0.7373)	5.6399	4	0.90
2	2.1017 (0.6649)	5.3242	5	1.10
3	2.0321 (0.6616)	5.0663	12	2.60

* Primal specification

The mean value and number of efficient schools using specification 2, which decomposes SAT scores into verbal, numerical and analytical ability scores in place of total SAT scores in the production model, are higher than those of specification 1. This result may be because schools are likely to be better when they are estimated by various subjects (i.e., verbal, numerical and analytical abilities) rather than the total ones. The mean value of efficiency and number of efficient schools of specification 3 are higher than those of specification 2. One likely explanation of this result is that the production model of specification 2 is a 'subset' of specification 3, which has more input/output variables. As more variables are included into the model, the greater is the chance that some inefficient schools will become efficient [26]. Having more variables in specification 3 will thus generally lead to higher average efficiency and more efficient schools, vis-à-vis specification 2.

To ascertain the efficiency results in "jackknifing" sensitivity approach, DEA results are tested to find the extent to which there were extreme outliers which affected the frontier, efficiency scores, and efficiency ranking in each of the DEA model specifications. For example, in the case of specification 1, each efficient school was dropped out one at a time in sequence, without replacement, and then the DEA model is re-estimated. The similarity of efficiency ranking between the DEA results with all schools included and those based on dropping out each efficient school one at a time was tested by the Spearman rank correlation coefficient. The mean efficiency from the iterations was also calculated. The results are summarized in Table 4.

TABLE 4
STABILITY OF DEA RESULTS TO OUTLIER SCORES, SPECIFICATIONS 1 – 3

Specification	No. of Efficient Schools	Range in Spearman Rank Correlation	
		Min	Max
1*	4	0.8548	0.9991
2	5	0.8770	0.9999
3	12	0.8947	1.0000

* Primal specification

The high rank correlation coefficients show that the rankings are relatively stable in regard to outlier schools determining the efficiency frontier. From the table, the variation of rank correlation coefficient was lowest in specification 1, ranging from 0.8548 to 0.9991. In other specifications, the ranking correlation was somewhat more stable, ranging from 0.8770 to 1.0000 in specification 2 and 3. As the outliers may affect to the stability of efficiency scores and ranking, e.g., due to the extreme difference of input-output combination, Specification 1 was somewhat more sensitive to outliers. Moreover, the greater the number of inputs and outputs in the additional DEA specifications, the greater the apparent stability of the DEA efficiency scores is in regard to outlier schools.

IV. CONCLUSION AND POLICY IMPLICATIONS

This study proposes the DEA technique to measure school efficiency, as DEA has been recognized as a practical method for this purpose. DEA uses benchmarking to measure efficiency of each school relative to others in its group. Such comparisons can assist in identifying efficient and inefficient schools within the group as well as indicating potential adjustment targets for the inefficient institutions. The empirical results reveal that the schools under observation, on average, operate inefficiently. To ascertain the robustness of the analytical framework and resulting measures, a sensitivity analysis was conducted by introducing two other specifications, different from the primal one. This was to examine whether modifications in the educational production function would result in substantive changes in the empirical findings on school efficiency. For each specification, the efficiency measures were re-estimated using the DEA model. Under jackknifing method, by dropping each outlier or efficient school one at a time in sequence without replacement and then the DEA model is re-estimated, the results suggest that efficiency ranking correlation was stable for all specifications. Moreover, under Spearman rank correlation, based on various additional school inputs and outputs, the results also indicate that the ranking between all specifications were almost similar.

This study, if validated, may have wide implications for national education policy. The performance-based DEA results indicate that the schools under observation, on average, operate inefficiently. Schools under observation have both efficient and inefficient schools and the adjustment targets of inefficient institutions, e.g., of SAT scores, indicate the extent to which these schools can improve their performance. If validated by further research, the findings could be used to prioritize institutions for treatment. In addition to allocating budget based on block grants or enrolments, policy-makers may use performance-based analysis to identify which institution will yield higher marginal returns, and which individual institution will give the most marginal returns.

For the future research direction, this study employs data only from public general upper secondary schools in Northern

Thailand; therefore, the principal limitation of this study is in the ability to generalize its findings to other level of educational institutions, or in other types of societies which is a limitation of studies in general. Moreover, this study assessed school performance through efficiency analysis only for a given period. Future research could focus on analyzing over a longer time or across subgroups or regions in a panel data setting. By doing so, a fuller understanding on the school efficiency analysis as well as the robustness of resulting measures on efficiency may be achieved. Further, this study uses inputs and outputs of the educational production function that may not be fully amenable to the other types of schools. Future studies might refine the inputs and outputs based on the objectives of each school type.

APPENDIX

DESCRIPTIVE STATISTICS OF INPUT, AND OUTPUT VARIABLES

Variables	**Mean (S.D.)**	**Min.**	**Max.**
Schools (n = 455)			
Inputs			
Teacher-student ratio (%)	4.77 (1.3945)	1.73	11.35
Proportion of students not from low-income families	0.52 (0.1966)	0.01	0.97
Teaching aide-student ratio (%)	0.60 (0.2828)	0.00	1.94
Outputs			
Passing	381.31 (381.3945)	9.00	2,389
Graduates	114.98 (119.9489)	2.00	779
National test score (SAT)	36.01 (5.5340)	25.45	67.81
SAT - Verbal Ability	13.33 (1.6837)	9.73	23.08
SAT - Numerical Ability	12.24 (2.2635)	8.00	26.00
SAT - Analytical Ability	10.44 (2.0142)	6.77	21.51

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E-learning and Blended Learning in the Gulf Region

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Abstract

In today's ultra modern world the traditional face to face (F2F)teaching has been replace by e-learning or online learning .Companies find this method very effective to train their employees without using up work hours. E-learning has been implemented by many educational institutions at undergraduate and graduate level in the Gulf region. Blended learning has been adopted by many schools and universities in the Gulf. Blended learning is e-learning along with onsite support. This paper will discuss different modes of e-learning, assignment design techniques and E-learning trends in the Gulf region.

I. Introduction

There has been an increase in the number of universities and colleges implementing in E and blended learning as an integral part of instructional activities. They are trying to make best use of the technology available to promote e-learning and to motivate students to study outside the four walls of a classroom. These technological innovations have a direct impact on current university practices policies and have the potential of changing our traditional definition of education [1].E-learning can also mean extended learning that is learning outside the class room, from anywhere and at anytime.
Many schools in the gulf region are adopting this innovative style of teaching. Students find it interesting compared to the traditional method of teaching. Web-based instruction is already revolutionizing how students work, think , and access information [5].Some schools are using the free Learning Management Systems like 'Moodle ' which provides all the essential features required for blended learning.

Universities are also adoption tools like Blackboard.com and WebCT for online support along with the onsite teaching support. This can also be integrated with some classes being held in the second life which is 3D virtual world.

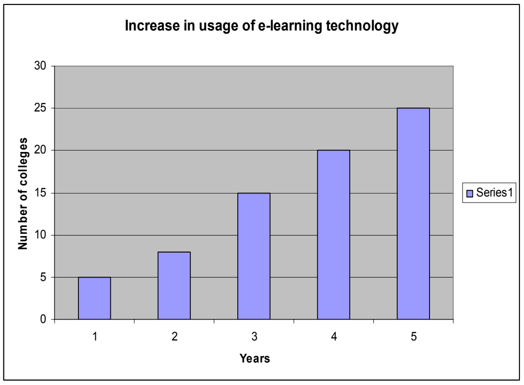

Figure1, increased usage of e-learning technology

As depicted in Figure 1, a recent survey conducted shows an increasing interest in e-learning over the years in the Gulf. Most of the universities in the gulf have a 'e-learning center for excellence'. It is very helpful at university levels for students who are working or who are frequently traveling to keep in touch with what is happening in their classes. It allows students who find it difficult to speak up in class to participate in online discussion forums. The students can participate in the online class discussion during their free time by logging on to the online class and posting his views to the discussion folder in an asynchronous mode.

The lecturers and teachers are able to save a lot of more time which can be utilized to develop and improvise on the course material.

E-learning can be very beneficial for students who are interested in continuing education along with their jobs and for people who have a lot of

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experience in the field or are currently working in the same field and want to enhance their knowledge about the subject. It does not require you to be physically present at a particular location. You can login to your class anytime from anywhere .This definitely saves a lot of time and helps the student to continue working while studying which is one of the major advantages. E-learning is a boon to specially those who have difficulty in travelling to and forth to attend the classes at the university.

II. Modes of online learning

A. Asynchronous mode

Online learning usually has two modes one is a completely asynchronous mode and synchronous mode. In case of asynchronous mode the lectures, assignment and examination questions are uploaded and available to the students online. The students can study from the lecture notes and specified text and then attempt the quizzes and question uploaded. There is no synchronised session between the lecturer and the student. Any query by the student will be send to the lecturer's mail id, who will then reply it within 24 hours in most of the online programs. Students used to the traditional mode of teaching may feel a little lost initially but will be able to cope up with online teaching.

B. Synchronous mode

In case of synchronous mode, the students and the instructors are required to login to the class at a particular time decided in advance. The lecturer will then conduct the class using PowerPoint presentation which will be visible to the student on his screen. There are many advance softwares that support this facility. The student will be able to listen to the explanation given for each of the slide displayed .He can ask a question to the instructor by clicking on an ion provided for the same which is very similar to raising your hand in the class to ask a question.
In this case you can have an experience of a virtual class room. The only drawback in this case is that the student should login to the class at a specific time given. This may be difficult and impossible for students who are constantly travelling. E-learning involves online class discussions where the students can login in their own free time and posting their opinions and views on the topic of discussion. The students are encourages to read each others suggestions and give their view about it. Data collected for this research shows that students enjoy the discussion session the most. It motivates them to login into the class more often.

III. Just-in-Time Teaching

"One Web-based approach, Just-in-Time Teaching (JiTT), was first devised by Novak, Patterson, Gavrin , and Christian (1999) to teach problem solving in physics" [3].This can be incorporated into online teaching .The students can be given assignments after every class and based on their performance in the assignment, the next lecture could be modified to suit the requirement of the class such that the it addresses the concepts the student have not understood correctly.
Universities in the Gulf region have adopted both these modes of e-learning. Many colleges in the U.A.E. prefer having a blended mode of teaching which is online teaching (asynchronous or synchronous) and onsite teaching(face to face) teaching.

IV. Designing Assignments

Assignments could be multiple choice questions or essay type questions. There are number of software vendors who provide standard softwares to support e-learning needs.. WebCT provides a facility wherein it is possible to create a question bank and then select the question for multiple choices. These questions banks are also available in the market for certain courses. These could be material that is designed for certain e-learning tools. eg. In WebCT, the instructor can select the required questions from the database of questions.
E-learning is not only converting text into an electronic form, it is making content more interactive and interesting with more audio and video effect.

The content design should be student centred. . From [4], a number of studies in recent years have highlighted critical aspects of learner readiness that need to be addressed. Some of these include:

1. Technology skills
2. Access to Technology
3. Technology Literacy and
4. Self-regulated learning

Points 1 to 3 can be addressed easily by the universities in the Gulf .Learning at self pace is a challenging task to achieve due to the fact that the courses are always designed for a particular period of time.

Online Group Projects:
It is very effective as the class can be divided into groups by the instructor and assigned different projects. Separate folder can created for each group. The student can use these folders to post their finding so that it is available to everyone within the group. They can also use the discussion forum or the chat session as a virtual meeting place. Instructor can keep a track of their participation and progress.

V. Other tools used for e-learning

E-learning classes could also be designed in Second Life. Second Life is a 3-D virtual world. There are virtual colleges and universities in the second life which have virtual classrooms and labs where experiments are carried out just like in a actual class room .This is very beneficial for some online programs .One such example could be a Chemistry class where experiences can be carried out in the virtual world. All the virtual chemicals used exhibits all the properties of the actual chemical. This also gives the student to explore and experiment without fear of any dangerous accidents. There a number of organizations in the Gulf region which provide training classes for flying a plane or driving a car is also provided online.
Colleges and universities are also using technologies like pod casting, wikis and blogs. Colleges, universities and schools in the Gulf are encouraging students to create e-portfolios which can then be given to potential employers.
An e-portfolio can be a web-based information management system that uses electronic media and services. The learner builds and maintains a digital repository of artifacts, which they can use to demonstrate competence and reflect on their learning. Having access to their records, digital repository, feedback and reflection students can achieve a greater understanding of their individual growth, career planning and CV building. Accreditation for prior and/or extra-curricular experiences and control over access makes the e-portfolio a powerful tool [2].

Mobile learning is a complete anywhere ,anytime learning technology.As shown in the figure it can acquire data and learning material not only from the internet but also from other mediums. Due to the successful development of Bluetooth, WAP (Wireless Application Protocol), GPRS (General Packet Radio System) and UMTS (Universal Mobile Telecommunications System), the technological structures for wireless telephony and wireless computing are now ready for use in the field of teaching. In most parts of the world wireless technologies and applications are replacing wired ones: e-Commerce is moving to m-Commerce; m-Business is replacing e-Business. The move to wireless technology in telephony and computing is irreversible.

In the education filed there has been a gradual change from traditional onsite learning to electronic learning (e-Learning) to mobile learning (m-Learning).

VI. Conclusion

The is a tremendous and fast increase in the number of colleges in the Gulf adopting for e-learning .E-learning is a very effective tool to making learning a very enjoyable and interesting experience. E-learning requires smart assignment design .The latest learning tool is the m-learning or mobile learning which is portable and a truly anywhere anytime technology. Further study needs to be conducted based on the technology used and favoured the most in the Gulf.

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Scene Change Detection for Uncompressed Video

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***Abstract*—In this paper, we present a scene change or shot boundary detection method based in the changes in entropy of differences between uncompressed video frames. As in the uncompressed domain, cues for scene or shot boundaries are not available, detecting video content features is a non-trivial and typically requires additional complexity in the evaluation. The entropy presents a metric for the complexity of information. Used on the differences between video frames, the entropy is able to measure the complexity of changes. We find that due to content dependency, however, the relative entropy changes in the sequence of video frames is a better indicator for detection.**

An evaluation of the presented approach finds that detection for a combination of video test sequences can be reliably performed using the U component of uncompressed YUV 4:2:2 video only.

I. Introduction and Related Work

The domain of video annotation, indexing, and retrieval has attracted a large body of research in the past. One of the main drivers for this area of research is the readily available computing power in normal desktop computers, digital video equipment, and motivation to share content over the Internet in various forms of access models, i.e., sharing via web pages, live streaming, and so on. It is expected that the amount of digital video that is available will continue to grow. With this vast amount of data available, annotation and logical indexing of video becomes a desired feature. One standard for the annotation of multimedia data is MPEG-7, see, e.g., [1]. Amongst different approaches to annotation, segmenting the video into its scenes or shots is the most intuitive and basic. Several different approaches exist to detect shot boundaries in video, see, e.g., [2], [3] for an extensive overview of different algorithms and their classifications.

Reliable and universal detection of scene changes or shot boundaries in the uncompressed domain in a fast manner, however, is still a challenge. While in the compressed video domain, typically cues can be obtained that are readily available from the encoded video stream (e.g., motion vector intensity or transform coefficients), these cues are not available in the uncompressed domain. To alleviate this problem, the authors in [4] employ a two-stage histogram-based method to determine scene changes and filter out unwanted false detections. More sophisticated approaches have to implement additional methods, such as edge detection, see, e.g., [5]. Other venues of research employ neural networks to determine scene changes based on several pixel- and color-based features of uncompressed video, see, e.g., [6]. In [7], the authors apply fuzzy logic approaches to detect scenes. Recently, the authors of [8] employed an autoregressive model based on the color histogram in the uncompressed domain to determine scene changes.

In the following, we present a scene detection algorithm that is solely based on the entropy of differences between frames. The motivation for using this approach is that with changes between frames, the entropy of the differences will increase. We evaluate the algorithm against a short video test sequence and a *Combined* video sequence, which is derived from multiple test sequences. We present the performance metrics precision and recall obtained with the proposed algorithm before we conclude.

II. Entropy of Frame Differences

The scene boundary detection method introduced in the following is applied on uncompressed video frames using the YUV 4:2:2 format. This format is typically used for video coding and transcoding for a variety of video codecs. The YUV format describes each individual pixel by its luminance (Y) and two color differences (U) and (V), also known as chrominance components.

We denote the i-th byte in the n-th frame out of $n = 0, 1, \ldots, N$ frames as $F_n(i)$. Furthermore, let $Y_n(i_Y)$ denote the luminance byte values and $U_n(i_{UV})$, $V_n(i_{UV})$ denote the i-th byte values for the two chrominance components. Note that due to the chroma sub-sampling, $0 \leq i_{UV} \leq \frac{i_Y}{4}$, i.e., the two chrominance components are restricted to half the resolution of the luminance component. Sub-sampling is used since the human eye is most sensitive to the luminance component. In the 4:2:2 format, the U and V values are each sub-sampled for a group of 4 luminance pixels and stored by component in a grouped manner on disk. The manner in which the individual values are sub-sampled and typically stored on disk is illustrated in Figure 1 for an individual frame.

We denote the probability for a specific byte value $F_n(i)$ in frame n as p_{F_n} with $F_n(i) \subset \{0, \ldots, 255\}, \forall i$. The entropy gives a measure for the complexity of an individual frame's information content. The entropy for the byte values of frame n is calculated as in Equation 1.

$$H_n = -\sum_{b=0}^{255} p_{F_n} \cdot \log_{256}(p_{F_n}) \tag{1}$$

The entropies for a frame's three individual components can be calculated in a similar manner.

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In order to derive a better estimator for the changes between frames, we calculate the entropy for the differences between frames n and $n-1$ for all frames $n \geq 1$. The differences between two complete frames are calculated as in Equation 2.

$$F_{n,n-1}(i) = |F_n(i) - F_{n-1}(i)|_{\forall i} \tag{2}$$

The entropy for the frame differences is then calculated as in Equation 1 for $p_{F_{n,n-1}}$. The entropy of the difference frames (or the differences frames' components) can then be used to determine the scene boundaries by comparing subsequent difference frame entropies. We note that this approach requires at least three frames to be processed, as illustrated in Figure 2.

III. Scene Change Detection Method

The initial evaluation of the algorithm presented in this paper is performed on the *News* sequence in the QCIF format ($i = 38016, i_Y = 25344, i_{UV} = 6336$). This sequence features two news anchors and a changing background with varying displays of dancers, as illustrated in Figure 3. Details for the *News* video sequence's content are provided in Table I. We illustrate the entropy for the frame differences in Figure 4. We observe that the entropy of frame differences "spikes" where the content of the underlying video sequence changes at frames 91, 262, and 241. This "spike" of the entropy can be used to detect the changes in scene content.

For the evaluation of the scene change algorithm introduced in Section III with respect to shot boundary detection, we now employ a *Combined* video sequence in the QCIF format, which is derived by concatenation of multiple video sequences. The sequences' details are given in Table I. The resulting entropy for the differences between complete frames $F_{n,n-1}$ is illustrated in Figure 5. We initially observe that the changes between individual scenes are represented by spikes in the entropy of the differences between full frames. We additionally observe that for each original sequence, a separate level and behavior of the entropy of frame differences can be observed in Figure 5. The scenes containing more motion and camera movement exhibit more varying entropies. For the *Husky* sequence, a generally high level of entropy is observed, while the *Bow* sequence's entropy exhibits more pronounced changes or "spikes" of the entropy.

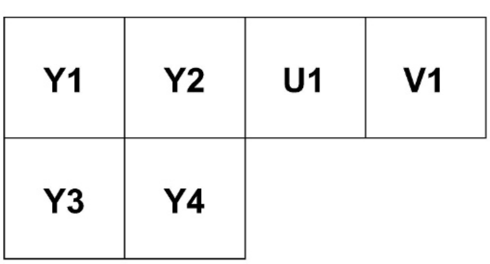

Fig. 1. YUV 4:2:2 pixel format and single video frame storage.

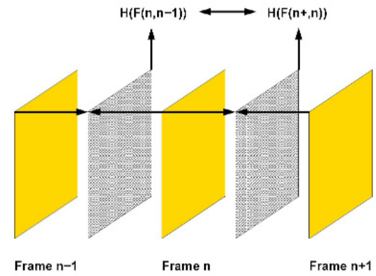

Fig. 2. Calculation of difference frames and entropy values.

Sequence	Frame	Content
News	0	A news sequence with two anchors and varying background.
	91	Background is one dancer close-up.
	151	Background is two dancers.
	241	Background is one dancer close-up.
Salesman	301	A salesman presents his product.
Akiyo	750	A news anchor talks in front of a static background.
Husky	1050	Several runners and their dogs, with some camera panning and zooming.
Bow	1300	A person enters, bows, and leaves.
Hall Monitor	1600	A hall monitor with people passing by.

TABLE I
Details for the concatenated *Combined* video sequence.

The entropy of the differences for the individual frame components is illustrated in Figure 6. We observe that overall, all three individual components exhibit similar characteristics of the entropy compared to the complete frame. We note, however, that the two chrominance components exhibit a significantly lower level in their entropy values than the luminance component for the *Husky* and *Bow* sequences. We conclude that comparing the entropies of the difference frames for identification of scene boundaries itself is not advisable with respect to the different levels of entropy due to the content differences.

When the change in the entropies of the frame differences is evaluated, however, the scene changes can be detected

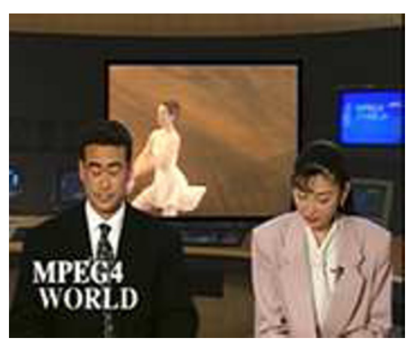

Fig. 3. Example screenshot of the *News* video sequence.

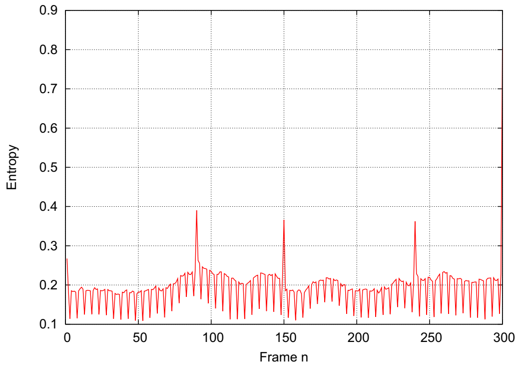

Fig. 4. Entropy of the frame differences for the *News* QCIF video sequence.

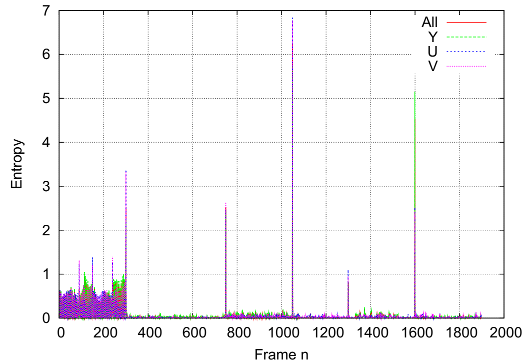

Fig. 7. Relative entropy changes for the frame differences of the *Combined* QCIF video sequence.

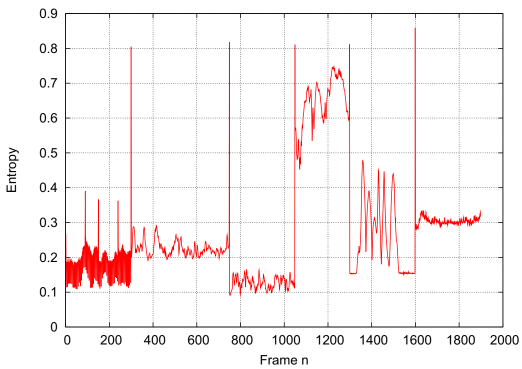

Fig. 5. Entropy of the frame differences for the *Combined* QCIF video sequence.

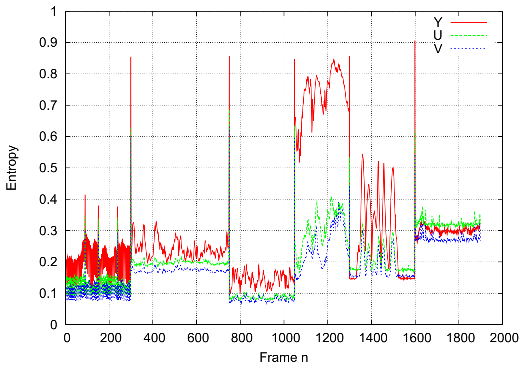

Fig. 6. Entropy of the frame differences for the individual Y,U, and V components of the *Combined* QCIF video sequence.

in a manner that takes the underlying content into account. As illustrated in Figures 5 and 6, the level of the entropy changes with the scene's content. The relative changes in the entropy values are hence a better estimator to determine scene boundaries. We calculate the relative entropy changes as

$$H_{n,n-1} = \frac{|H_n - H_{n-1}|}{H_{n-1}}. \quad (3)$$

The resulting relative entropy changes are illustrated for *Combined* video sequence in Figure 7. We initially observe that for the first part of the *Combined* video sequence, a fairly high level of noisy changes in the relative entropy can be examined, whereas this behavior is not visible for the other parts of the sequence. This behaviour can be explained by the background video in the *News* video sequence, see Figure 3. Thus, this behavior is content-dependent. Secondly, a closer examination of the "spikes" in the relative entropy yields that they occur at the scene change boundaries. We also note that these "spikes" are at least in the region of 100 percent changes in the relative entropy. This leads to the conclusion that changes of more than 100 percent in the relative entropy are indicators of scene changes.

To detect scene changes following this approach, we define the threshold for the detection as

$$H_{n,n-1} \geq t. \quad (4)$$

IV. Performance Evaluation

Typical performance metrics for the detection of shot and scene boundaries are *Recall* and *Precision*. The recall value presents a measure for the correct detection of changes, whereas the precision measures the correctness of detected changes. Let D denote the correct number of detections, D_F denote the number of false detections, and D_M denote the number of missed detections. Recall and precision can then

TABLE II

PRECISION AND RECALL VALUES FOR DIFFERENT THRESHOLDS FOR THE *Combined* VIDEO SEQUENCE.

Thres.	All		Y		U		V	
t	Prec.	Rec.	Prec.	Rec.	Prec.	Rec.	Prec.	Rec.
1	1	0.5	1	0.875	1	1	1	0.875
1.1	1	0.5	1	0.875	1	1	1	0.875
1.25	1	0.5	1	0.75	1	0.75	1	0.75
1.5	1	0.5	1	0.5	1	0.5	1	0.5
2	1	0.5	1	0.5	1	0.5	1	0.5

be calculated as

$$\text{Recall} = \frac{D}{D + D_M} \tag{5}$$

$$\text{Precision} = \frac{D}{D + D_F} \tag{6}$$

For the review of the proposed method on the *Combined* video sequence, we provide the values for precision and recall in Table IV for different thresholds t of the relative entropy. We observe that precision for the entropy of the complete frame differences is high for all components combined and individually. We furthermore note that there is no impact of different threshold levels on the precision. For the recall values, on the other hand, we observe a low value for the complete frame's entropy and slightly higher values for the Y and V components. Overall, only the U component yields complete detection of all scene changes with a threshold level close to 1.

An additional observation from this characteristic is the time required to parse the complete video, especially if resolutions above QCIF are considered. As the U component's size in bytes is only $\frac{1}{6}$ of the complete video frame's size, the scene detection speed can be greatly increased.

V. CONCLUSION AND OUTLOOK

In this paper, we presented a method to detect scene changes or shots based on the relative changes in the entropy of difference frames in the uncompressed domain. As the differences between frames increase, the entropy will increase as well. However, due to content dependency of the level and behavior of the entropy, we use the relative changes in the entropy of differences between frames for detection. We found that based on the performance metrics precision and recall, the fasted and most reliable approach to detect scene changes or shots is to calculate the relative entropy differences for the U component only.

Future research venues will include evaluation of the detection method presented herein for a larger variety of video content and additional refinements to detect additional changes in the underlying video based on the entropy of the frame differences.

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ZigBee Performance in 400 KV Air Insulated Power Substation

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***Abstract*-An experimental assessment of the impact of the electromagnetic environment of a 400 kV substation on the performance of ZigBee equipment is described. The experimental assessment includes a pragmatic field trial and a laboratory test. The laboratory test, in which all external noise and interference are excluded, is used as a control. A simple set of metrics are used to compare the performance of ZigBee equipment deployed in the substation with that deployed in a controlled laboratory environment. The results based on more than 1.6 Gbit of transmitted data show no significant adverse impact of the substation electromagnetic environment on the performance of ZigBee equipment**.

*Keywords***:** ZigBee, partial discharge, power substation, IEEE 802.15.4.

I. Introduction

The infrastructure investment in a national power transmission system is colossal. It is therefore necessary to operate such systems as efficiently as possible, consistent with maintaining acceptable security of supply. Efficient and reliable operation demands continuous monitoring of the system state resulting in instrumentation and control equipment being widely scattered throughout substation compounds. Information and control signals for both normal and abnormal operation are traditionally connected, using cables or optical fibres, to a SCADA (Supervision, Control and Data Acquisition) system [1] and/or its successor UCA (Utilities Communication Architecture) system [2]. Ethernet local area network (LAN) implementations of such UCA/SCADA systems, which simplify the addition/reconfiguration of instrumentation and the coordination of protection systems, have been proposed and are already being evaluated [3].

Significant flexibility and cost advantages over a wired LAN infrastructure would be gained, however, if signals could be routed around electricity substation compounds wirelessly. Furthermore, wireless communication technologies hold out the prospect of 'hot-line', sensors that can be deployed on energized high-voltage (HV) equipment without the inconvenience and costs associated with bridging the system's primary insulation [4, 5]. WLAN and WPAN technologies represent obvious opportunities to realize these advantages.

The casual deployment of wireless technologies for critical functions is not, however, without risk. Whilst the naturally occurring noise environment is relatively benign at WLAN and WPAN frequencies [6] the man-made noise environment within a substation compound is complex and hostile due, for example, to PD from imperfect insulation and sferic radiation from switching and fault transients. (The term sferic usually relates to radiation from a lightening event but is used here as a shorthand for similar radiation arising from any large current transient.) The latter is of particular concern since it is on just such occasions that control and protection equipment is required to operate reliably. It is possibly for this reason that UCA demonstration systems have until now employed a 'wired' (often fibre) transmission medium e.g. [7].

An investigation into the vulnerability of WLAN and WPAN technologies to impulsive noise in electricity transmission substations has been proposed [8]. One of the project objectives requires an assessment of ZigBee technology in impulsive noise environments and its suitability for deployment in HV substations. As part of this assessment a laboratory test and field trial of ZigBee equipment have been carried out.

The field trial comprises a deployment of ZigBee equipment in a 400 kV electricity supply substation. The laboratory test replaces the antennas and radio path between Zigbee transceivers with high-quality coaxial cable and appropriate microwave attenuators.

This paper describes partial discharge as observed in electricity supply substations, briefly reviews the relevant aspects of ZigBee technology, and presents the results of both laboratory test and field trial.

II. PD in Substations

An electrical discharge is partial if it fails to fully bridge the space between a pair of electrodes. It can occur around an electrode in a gas (corona), within gas bubbles in a liquid or within the space created by voids in a solid. HV plant (transformers, switchgear, cables etc) is especially prone to PD

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if its insulation is damaged and/or as its insulation ages. If remedial action is not taken the insulation can be seriously compromised leading, ultimately, to catastrophic failure. PD current pulses in strong insulators (e.g. SF_6) can have rise-times as short as 50 ps and may contain significant energy at frequencies up to 3 GHz [9]. Such impulsive signals can give rise to electromagnetic resonances within the conducting enclosures in which they occur.

PD propagation within a Gas Insulated Substation (GIS) is by a combination of transverse electric (TE), transverse magnetic (TM) and transverse electromagnetic (TEM) modes [10]. Laboratory tests have suggested that two principal mechanisms are responsible for PD signal damping. These are reflections due to characteristic impedance discontinuities (such as is caused by spacers) and energy conversion from TEM to TE or TM modes [11]. Although the character of PD appears to have some dependence on the size and geometry of plant components (e.g. insulating spacers, L-shaped buses, T-branch buses) damping typically appears to become significant somewhere between 100 MHz and 300 MHz and increases with increasing frequency above this [12]. PD energy in the frequency range 0.5 - 1.2 GHz, however, is readily radiated from apertures formed, for example, by insulating spacers or bushings [13].

Energy from PD processes can be radiated whenever spectral components arising from current pulse edges extend into the radio frequency (RF) region [14]. Signals radiated from open-air substations are typically stronger than those from underground substations due, in the latter case, to an enclosing metallic tank located in a steel-reinforced concrete building [15].

III. ZIGBEE

ZigBee is a specification of a network and security services application layer technology developed by the ZigBee Alliance and based on the IEEE 802.15.4 standard. It is a low-cost, low-power, two-way wireless communications technology. It is primarily intended for domestic and commercial applications e.g. home and building automation, PC peripherals, toys and games but also finds application in other contexts, e.g. medical sensors and industrial control [16]. The IEEE 802.15.4 standard addresses the physical (PHY) and media access control (MAC) layers and defines a 250 kbit/s, 32-chip, direct sequence spread spectrum (DSSS), offset quadrature phase shift keying (OQPSK) radio signal operating in the 2.4 GHz unlicensed Industrial, Scientific and Medical (ISM) band. Alternatives bands exist around 868 MHz and 915 MHz. From a total of 27 frequency channels, one lies in the 868 MHz band, ten in the 915 MHz band and 16 in the 2.4 GHz band. In addition to providing link-layer security including access control, confidentiality, message integrity and optional message freshness, it employs network- and application-layer security services, a 128-bit link key to secure pair-wise communications and a 128-bit network key to secure broadcast communications [17]. A commercial system-on-chip implementation of a 2.4 GHz IEEE 802.15.4 compliant transceiver is already available [18, 19].

Previous work on the impact of interference on ZigBee systems has concentrated on the coexistence of this technology with similar technologies, especially WLAN and other WPAN transceivers. ZigBee has been shown to be potentially vulnerable to IEEE 802.11b (WiFi) and IEEE 802.15.1 (Bluetooth) transmissions. An analytical model suggests, however, that the IEEE 802.15.4 network should have little effect on the performance of IEEE 802.11b networks [20]. It has been concluded, from practical measurements, that IEEE 802.15.4 transmissions produce no significant impairments on the operation of IEEE 802.11 equipment, but that the converse is not necessarily true, i.e. IEEE 802.11 transmissions might degrade the performance of an IEEE 802.15.4 network [21]. The measurements reported appear to show that interference from IEEE 802.11b transmissions does not significantly impact IEEE 802.15.4 performance providing a physical separation of at least 8 m is maintained [22]. (References [21] and [22] suggest that a frequency offset of at least 7 MHz in operational frequencies is required for a satisfactory IEEE 802.15.4 performance.)

The authors are not aware of any similar work to establish the interfering effects on ZigBee transceivers of impulsive noise of PD origin as found in electricity supply substations. The practical field trial and laboratory test described in section 4 address this.

IV. FIELD TRIAL AND LABORATORY TEST

The field trial was carried out at Strathaven 400 kV Air Insulated Substation (AIS). The trial assesses the performance of ZigBee in this challenging electromagnetic environment. The laboratory test was carried out in the Geoffrey Smith Intelligent Dynamic Communications Laboratory at the University of Strathclyde. The laboratory test represents a control, i.e. a test which replicates that of the field trial but excludes all external noise and interference. The methodologies are described below.

A. Field Trial

The field trial system consists of two terminals, one a data source and the other a data sink, as shown in Figure 1. The data source and data sink terminals comprise a ZigBee module interfaced to a laptop computer. The ZigBee modules are based on the Ember EM250 ZigBeeTM/IEEE802.15.4 chip. The RF

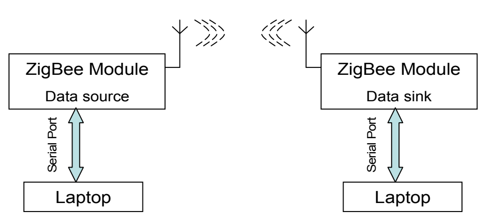

Fig.1. Field trial system

frequency band is 2.4 GHz and a total of 16 channels (IEEE 802.15.4 channels 11 to 26) are used. The maximum air-interface data throughput is 250 kbit/s. The maximum RF output power is 4 dBm. The receiver sensitivity with nominal 1% packet error rate is -98 dBm. Communication between the ZigBee module and the 2.33 GHz, 1 GB RAM, 120 GB HDD laptop computer is via an RS232 serial port.

The data source and data sink were located in different rooms of the 400 kV control building within the substation compound. The transmitter powers of the ZigBee modules were set to their maximum of 5 dBm. The separation between transmitter and receiver terminals was 21 m. The data sink signal strength indicator (RSSI) was -87 dBm which was 11 dB above the ZigBee receiver sensitivity. 21 m therefore represents close to the maximum separation in this environment. The serial port settings for interface between ZigBee modules and laptop computers are 115.2 kbit/s, 8 data bits, 1 stop bit, 1 parity bit (even) and hardware control flow.

Data was transmitted constantly from the source to the sink. Two transmission modes have been implemented; raw data transmission (mode 1) and data transmission with cyclic redundancy check (mode 2). In the former scheme data is neither encoded nor error checked. In the latter scheme data are CRC (cyclic redundancy check) encoded at transmitter and checked for errors at receiver.

All data transmissions are of pseudo fixed code blocks. The block lengths are 114 symbols for mode 1 transmissions and 65 symbols for mode 2 transmissions. These are the maximum block lengths specified by the ZigBee chip manufacturer.

The durations of the trials were a little more than four days and 10 days for mode 1 and mode 2 trials, respectively. These durations were chosen to yield a comparable volume of transferred data in both cases.

B. Laboratory Test

For the laboratory test terminal hardware, interface and settings were identical to those in the field trial. The communications channel between data source and sink, however, was replaced with a microwave cable and adjustable microwave attenuators, as shown in Figure 2. The cable and attenuators are specified for operation between DC and 18 GHz, and DC and 20 GHz, respectively. The ZigBee modules are enclosed in metallic boxes to provide shielding from external electromagnetic interference.

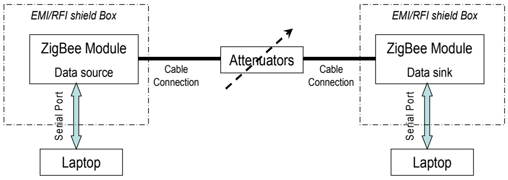

Fig. 2. Laboratory test system

The attenuators between source and sink modules were adjusted to give an RSSI of -84 dBm for mode 1 transmission and an RSSI of -87 dBm for mode 2 transmission. -84 dBm was found to be required for mode 1 transmissions (i.e. 3 dB more than that used for mode 2) in order to avoid complete system failure. This received power level therefore represented the minimum required to avoid the risk of transmission termination.

V. Results and Discussion

Data transmission errors can be caused by external noise and interferences or internal noise (including clock jitter). Two types of error can be distinguished: (i) symbol (byte) error and, (ii) symbol (byte) loss. Symbol error refers to a received symbol being different from that transmitted and is directly linked to bit errors. Symbol loss refers to symbols transmitted from the data source that remain detected at the data sink. Bit error ratio (BER), symbol error ratio (SER), symbol loss ratio (SLR) and overall symbol error and loss ratio (OSER) are used here as performance metrics.

ZigBee performance for mode 1 transmission is summarized in Table 1 for both field trial and laboratory test. Performance for mode 2 transmission is summarized in Table 2.

Table I shows that the mode 1 laboratory test SER and BER are better than those of the field trial by factors of 1.45 and 1.48 respectively. Laboratory test SLR and OSER, however, are worse than those for the field trial by factors of 3.65 and 3.59 respectively.

Table II shows that the mode 2 field trial SER, SLR, OSER and BER are worse than those of laboratory test by factors of 1.03, 1.60, 1.54 and 1.03, respectively.

These results taken together suggest that (i) symbol loss dominates symbol error and (ii) the electromagnetic environment of the substation did not significantly affect ZigBee performance.

For mode 1, symbol loss probability was greater for the ideal (laboratory) channel than in the substation trial, despite RSSI being 3 dB greater. It is thought that this may be explained by RF signal leakage from the antenna connector or PCB connector track arising due to the high attenuation path (> 73 dB) between data source and sink. Such leakage present in the electrically screened enclosure might be reflected back into, or otherwise recaptured by, the transmitter, thereby disturbing the module transceiver.

TABLE I

Performance Summary for Mode 1 (Raw Data) Transmission

	Field Trial	Laboratory Test
RSSI	-87 dBm	-84 dBm
Number of transmitted symbols	204,825,738	204,825,852
Symbol error ratio (SER)	1.9578×10^{-6}	1.3475×10^{-6}
Symbol loss ratio (SLR)	9.5691×10^{-5}	3.4928×10^{-4}
Overall symbol error & loss ratio (OSER)	9.7649×10^{-5}	3.5062×10^{-4}
Number of transmitted bits	1,638,605,904	1,638,606,816
Bit error ratio (BER)	5.2179×10^{-7}	3.5335×10^{-7}

TABLE II

PERFORMANCE SUMMARY FOR MODE 2 (CRC PROTECTED) TRANSMISSION

	Field trials	Laboratory Test
RSSI	-87 dBm	-87 dBm
Number of transmitted symbols	230,806,745	230,806,810
Symbol error ratio (SER)	2.7945×10^{-6}	2.7036×10^{-6}
Symbol loss ratio (SLR)	3.446×10^{-5}	2.1516×10^{-5}
Overall symbol error & loss ratio (OSER)	3.7252×10^{-5}	2.4219×10^{-5}
Number of transmitted bits	1,846,453,960	1,846,454,480
Bit error ratio (BER)	7.4196×10^{-7}	7.1813×10^{-7}

VI. CONCLUSION

A field trial to determine the practical performance of ZigBee technology operating in the severe electromagnetic environment of a 400 kV electricity supply substation has been described. A laboratory test which excludes all external noise and interference and which has been conducted as a control has also been reported. The results of trial and test suggest that there was no significant adverse impact on the performance of ZigBee technology by the electromagnetic environment (including partial discharge) of the substation.

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