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Editors' Introduction

WELCOME to the Spring 2011 issue of the Internetworking Indonesia Journal. This regular issue of the journal brings four (4) papers from a diverse background, covering a range from biomedical signals recognition to CDMA networks.

To our delight one of the papers is written in Bahasa Indonesia, something that is in-line with our aims of promoting the culture of writing good scientific papers in Indonesia. We feel that developing one's ability to express ideas, concepts and research methods/results in Bahasa Indonesia is an important step towards developing the habit of good research reporting – a skill that is transferable later when writing papers in English. As such, we see the IIJ also as "bridging" journal that fills a gap. Many Indonesian researchers are already able to produce good scientific papers in English, and thus are able to submit their papers to international conferences (e.g. IEEE sponsored conferences) and have access to these international conferences and journals. However, there remains the need for a national-level journal in Indonesia, one to which researchers who are comfortable writing papers in Bahasa Indonesia are able to submit their papers.

Another aim of the journal is to provide a publishing venue for graduate students who are completing their Masters (S2) or Doctoral (S3) studies. To that end we are delighted that one of the papers in the current issue of the journal was written by a Master's degree student. We feel it is important for the coming generation of students to begin writing papers early in their careers and to obtain experience in submitting papers to journals.

The first paper in the current issue of the IIJ focuses on biomedical signals recognition research. The paper describes the identification of *electrooculography* (EOG) signals related to eye movements, and proposes the use of wavelet transforms instead of the usual Fourier transforms. The paper describes the data acquisition environment used to conducts the research work, and suggests that researchers in this field look into the details of the energy and frequency bands distribution (from the eye movement signals) in order to obtain better interpretation of the EOG signals.

The second paper addresses a relevant issue in the area of software engineering. It focuses on the topic of test case generation, in which an automated approach to generating test-cases for a system is performed. The paper proposes the use of a three tier architecture containing several components, including a source code analyzer, an XML parser, a constraint analyzer and a test data generator. The approach employs the branch coverage criteria using the *Generalized Optimization Meta* heuristic (GOM) algorithm and *code constraint graph* (CCG) to efficiently maximize the coverage of all the branches in the test case. The work finds that test case generation is faster than with the simple genetic algorithm. This is due to the fact that the number of iterations for reaching the optimal solution is quick.

Traffic jam reduction and avoidance is the focus of the third paper, in which a literature survey is conducted on technologies that address the problem of traffic jams in highly populated areas. It surveys technical solutions that have proposed and adopted in some countries, including China and in Europe. The overall conclusion of the paper is that a combination of technical systems and regulatory approaches are needed in order to address the needs that are specific to the city or location in question.

Finally, the fourth paper – written in Bahasa Indonesia – looks into techniques to improve channel management in CDMA networks in order to provide a better success rate for SMS message transmissions and therefore better utilization of a given CDMA network. SMS transmissions experience high failures rates in the presence of a high volume of voice traffic. The paper, which is written by engineers and researchers at the TELKOM Research and Development Center (in Bandung, Indonesia), provides some research data that points to the need for CDMA operators to address channel management in anticipation of times of high voice traffic that may impact SMS message transmissions. Seeing that SMS messaging is today an important part of personal communications many developing nations, this topic is very relevant for the telecommunications industry in Indonesia.

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Wavelet Approach on Frequency Energy Distribution of Electrooculograph Potential towards Direction

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Abstract— **Biomedical signals recognition activity has been studied by many researchers. In this study, we describe the identification of Electro-oculography (EOG) signals of eye movement potentials by using wavelet transform which gives a lot of information than FFT. The capability of wavelet transform is to distribute the signal energy with the change of time in different frequency bands. This will show the characteristic of the signals since energy is an important physical variable in signal analysis. The EOG signals are captured using electrodes placed on the forehead around the eyes to record the eye movements. The wavelet features are used to determine the characteristic of eye movement waveform. This technique is adopted because it is non-invasive, inexpensive and accurate. New technology enhancement has allowed the EOG signals to be captured using the Neurofax EEG-9200. The recorded data is composed of an eye movement towards four directions, i.e. upward, downward, left and right. The proposed analysis for each eyes signal is analyzed by using Wavelet Transform (WT) by comparing the energy distribution with the change of time and frequency of each signal. A wavelet scalogram is plotted to display the different percentages of energy for each wavelet coefficient towards different movement. From the result, it is shown that the different EOG signals exhibit differences in signals energy with their corresponding scale such as left with scale 6 (8-16Hz), right with scale 8 (2-4Hz), downward with scale 9 (1-2Hz) and upward with scale 7 (4-8Hz).**

***Index Terms*—-** Electro-oculogram, Eye Movement, Signal Potentials, Scalogram, Wavelet Transform.

I. INTRODUCTION

The human eye is a spherical structure with a radius of 12mm. The signals that can be sensed from the movement of the human eyes can be known as *Electro-oculography* (EOG). The EOG is derived from the Cornea Retinal Potential (CRP) that is generated within the eyeball by the metabolically active retinal epithelium. The production of CRP comes from the hyper-polarization and de-polarizations of the nervous cells in the retina. EOG is the electrical recording corresponding to the eye movement. The eye has a resting electrical potential, with the front of the globe positive and the back with globe negative. This phenomenon was first observed by Emil du Bois-Reymond in 1848 and has been the foundation of electrooculography [1].

EOG are taken using bipolar electrodes on the outside of the eye. Exact electrode placements vary, but the electrodes are generally placed on the temples or on the distal ends of the forehead. When the eyes move, a differential potential result will occur. The magnitudes of the right and left eye movement can be seen between -75μV to 150μV respectively. The polarity of movement potentials is dependent on the electrode setup since the signal is positive when the eyes are moving toward positive electrode [1]. At present, EOG is used for the evaluation of occulomotor abnormalities such as nystagmus, strabismus, and supranuclear occulomotor dysfunction is briefly explained by [2].

EOG is a technique for measuring the resting potential of the retina. The resulting signal is called the electro-oculogram. The main applications are in ophthalmological diagnosis and in recording eye movements [3]. The EOG is a potential produced by movement of the eye or eye lid. The generation of the EOG signal can be understood by envisaging dipoles located in the eyes with the cornea having relatively positive potential with respect to the retina [4].

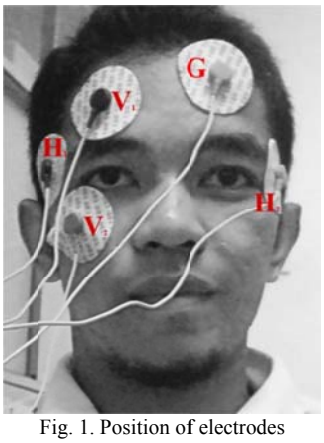


Fig. 1. Position of electrodes

This EOG signal is picked up by a bi-channel signal acquisition system consisting of the Horizontal (H) and Vertical (V) channels. The placement of the electrodes are

shown in Figure 1. The EOG signals are obtained by placing two electrodes to the right and left of the outer canthi (H_1, H_2) to detect horizontal movement and another pair above and below the eye (V_1, V_2) to detect vertical movement. A reference electrode is placed on the forehead (G). The overall connection is illustrated in Figure 2.

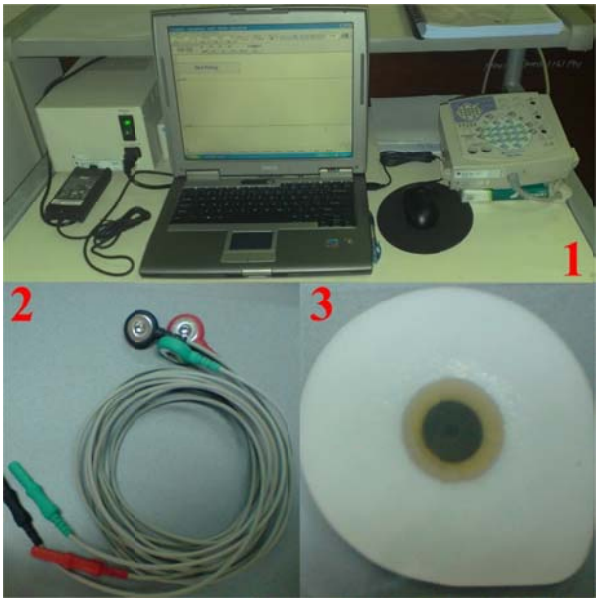


Fig. 2. (1) Data Acquisition system. (2) Electrode connector. (3) Disposable *Ag/AgCl* bioelectrode

Numerous other techniques from the theory of biomedical signal processing have been used to obtain representations and extract the features of interest for classification purposes. Dinesh [5] used the EOG signals for determining the angle of eye gaze for controlling a computer while Aysegul and Kara [6] used the EOG signals for the classification with Artificial Neural Network (ANN), and Sudirman [7] used the eye movement for the classification by using time frequency analysis. Study done by the Bhander [8] used the wavelet scalogram decomposition to determine the most energy in specific frequency bands of vertical eye movement. They found that 90% of the signal energy (90%) is concentrated in the lower or higher scales and signal denoising.

II. WAVELET TRANSFORM

Wavelet transform is a powerful tool in analyzing signals because of its ability to extract time and frequency domain information. The wavelet transform could be defined as an extension of the classic Fourier transform, except that, instead of working on a single scale (time or frequency), it works on a multi-scale basis [10]. Wavelet functions overcome the limitations of Fourier methods by employing an analyzing function that are localized in time and frequency. It has a finite energy function and can be represented on a transient signals.

In the previous studies as demonstrated by [11, 12, 13, 14, 15, 16, 17], wavelet analysis has developed excitement for the researchers in signal processing. It has been successfully implemented in various applications such as transient signal analysis, communication signals and other signal processing applications. Instead of Fourier analysis, wavelet analysis is set up within the expansion of functions in terms of a set of basic functions. Different from Fourier, it expands the function in terms of wavelets rather than the trigonometric polynomials in Fourier. It generates wavelets in the form of translation and dilation of a fixed function called the mother wavelet.

Wavelet functions overcome the limitations of Fourier methods by employing analyzing functions that are local in time and frequency. It is a finite energy function and can be represented on transient signals. In signal processing, wavelet analysis is used importantly in processing the non-stationary signals. The wavelet transform can be interpreted as a decomposition of the original signal into set of independent frequency channels. It is essentially the method of processing data from a continuous signal into series of signal decompositions represented at different frequency ranges. This is the use of the mother wavelet.

In signal processing, wavelet analysis is mostly used in processing non-stationary signals. The wavelet transform can be interpreted as a decomposition of the original signal into set of independent frequency compositions. The wavelet has a vanishing moment localized both in frequency and time. Assumption from the study done by Magosso [18] has brought us to this solution.

In both forms of wavelet analysis (continuous and discrete), the signal is decomposed into scaled and translated versions $\psi_{ab}(t)$ of a single function $\psi(t)$ called the mother wavelet:

$$\psi_{ab}(t) \triangleq \frac{1}{\sqrt{a}} \Psi\left(\frac{t-b}{a}\right) \tag{1}$$

where a and b are the scale and translation parameters respectively, with a, b $\in \Re$ and a $\neq$ 0. The continuous wavelet transform (CWT) of a signal s(t) $\in L^2(\Re)$ (the space of the square integrable functions) is defined as:

$$C_{ab}(t) = \int_{-\infty}^{\infty} s(t) \frac{1}{\sqrt{a}} \Psi^*\left(\frac{t-b}{a}\right) dt = \left\langle s(t), \psi_{a,b}(t) \right\rangle, \tag{2}$$

where the symbol * mean complex conjugation and < > the inner product. The discrete wavelet transform (DWT) is obtained by discretizing the parameters a and b. In its most common form, the DWT employs a dyadic sampling with parameters a and b based on powers of two: $a = 2^j$; $b = k2^j$, with j,k $\in$ Z. By substituting in Eq. (1), we obtain the dyadic wavelets:

$$\psi_{j,k}(t) = 2^{-j/2}\psi(2^{-j}t - k). \quad (3)$$

The DWT can be written as

$$d_{j,k} = \int_{-\infty}^{\infty} s(t)2^{-j/2}\Psi^*(2^{-j}t - k)dt = \left\langle s(t), \psi_{j,k}(t) \right\rangle, \quad (4)$$

By appropriately selecting the mother wavelet $\psi(t)$ the collection of functions { ψ j,k(t) j,k 2 Z} forms an orthonormal basis for $L^2(\Re)$. The correlated DWT allows the original signal to be reconstructed accurately and efficiently without any redundancy.

A. Wavelet Energy Distribution

The orthonormality of the set $\{\psi_{j,k}$ (t)j,k$\in$ Z} allows the concept of energy within the framework of the discrete wavelet decomposition to be linked with the usual notions derived from the Fourier theory. The energy series associated with coefficient series $d_{j,k}$ is given by

$$E_{j,k} = \left| d_{j,k} \right|^2 \quad (5)$$

and the overall energy at resolution j is

$$E_{j,k} = \sum_{k=0}^{2^{M-j}-1} \left| d_{j,k} \right|^2 \quad (6)$$

Hence, the total energy associated with the entire signal can be obtained as

$$E_{tot} = \sum_{j=1}^{M} \sum_{k=0}^{2^{M-j}-1} \left| d_{j,k} \right|^2. \quad (7)$$

Energy coefficients as computed by Eq. (7) have different localization and density over different frequency band depending on the scale. Therefore, in order to study and compare the different movement of energy at different scales, it is necessary to compensate for the halved time resolution at each scale due to the down sampling operation. These methods have been applied to the analysis of the EOG signals.

B. Wavelet Scalogram

Wavelet scalograms (refer to Figure 6 and Figure 7) represent the time frequency localization property of the discrete wavelet transform. In this plot each detail coefficient is plotted as a filled rectangle whose color corresponds to the magnitude of the coefficient. The location and size of the rectangle are related to the time interval and the frequency range for this coefficient. Coefficients at low levels are plotted as wide and short rectangles to indicate that they localize a wide time interval but a narrow range of frequencies in the data.

In contrast, rectangles for coefficients at high levels are plotted thin and tall to indicate that they localize small time ranges but large frequency ranges in the data. The heights of the rectangles grow as a power of 2 as the level increases. The bar shown on the scalogram plot indicates the range of energy for each scale. This energy is defined as the sum of the squares of the detail coefficient for each scale. The scalograms reveal that most of the energy of the signals in the data is captured in the details coefficient.

III. PROPOSED WORK AND METHODOLOGY

The system setting includes the EEG data acquisition system; Neurofax EEG-9100 software [19] with EOG electrodes set and the sampling interval is 1ms. The EEG data acquisition system is used to record EOG signals from the subjects. Independent measurements can be obtained from both eyes, but as both eyes move in the vertical direction, it is sufficient to measure the vertical motion of only one eye together with the horizontal motion of both eyes. *Ag/AgCl electrodes* are chosen as their half cell potential is closer to zero compared to other types such as silicon rubber electrodes. Figure 3 below shows the overall workings for the proposed study. This process was done in a quiet room to minimize the noise and hence get better recorded signals as shown in Figure 4.

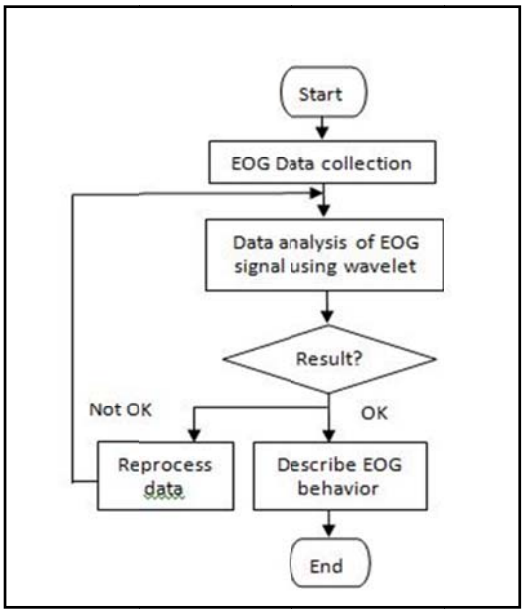


Fig. 3. Flow works of EOG signal processing

Subjects were seated on a chair and supervised by an instructor who gave instructions on how to move their eyes. The instruction composed of four movements that are upward, downward, left and right. The recording was done in four successive eye movements for 10 subjects and each subject repeated for three times. Initially, EOG was recorded for 20 to 30 seconds for each eyes movement. Unfortunately, since the subjects were showing signs of tiredness, the recording duration was reduced to 10 seconds which was free from artefacts observed in longer traces by visual inspection.

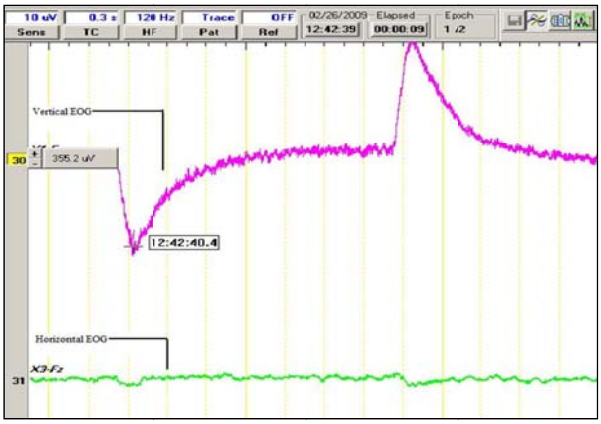


Figure 4: Vertical (pink) and Horizontal (green) EOG signal displayed from data acquisition system

The eyeball moved to the desired direction and the centre or static eye becomes the reference point. Furthermore, subjects were also asked to avoid blinking, body movements or any disturbances during the recording to minimize the unwanted artefacts. EOG signal captured was then analysed by using wavelet analysis from MATLAB software and toolbox application. Figure 5 is the real signal of the right movement of EOG signals by using MATLAB. It shows the basic characteristic of EOG potentials.

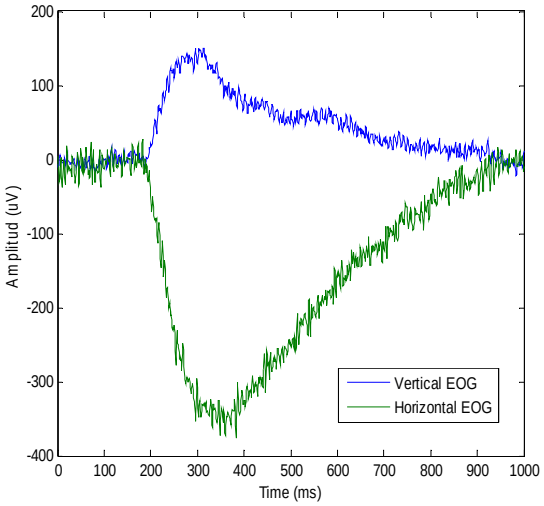
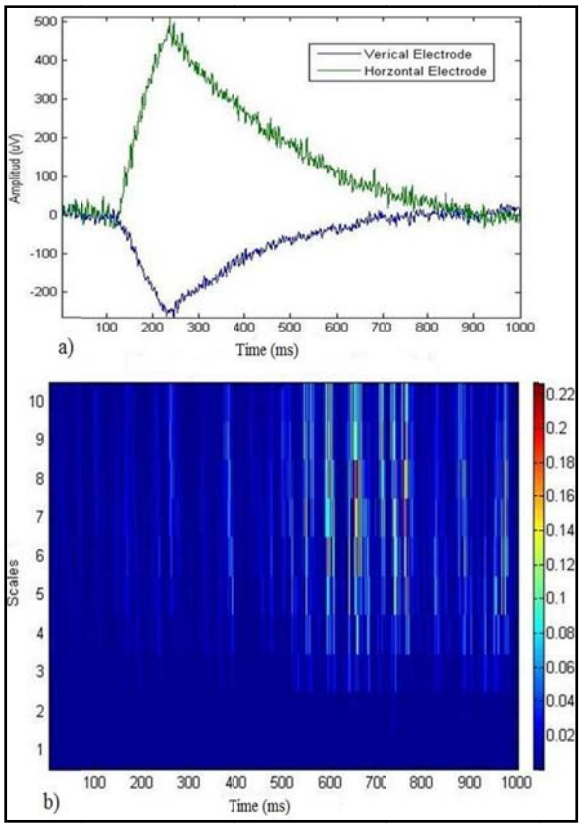


Figure 5: Right EOG signal plotted using MATLAB

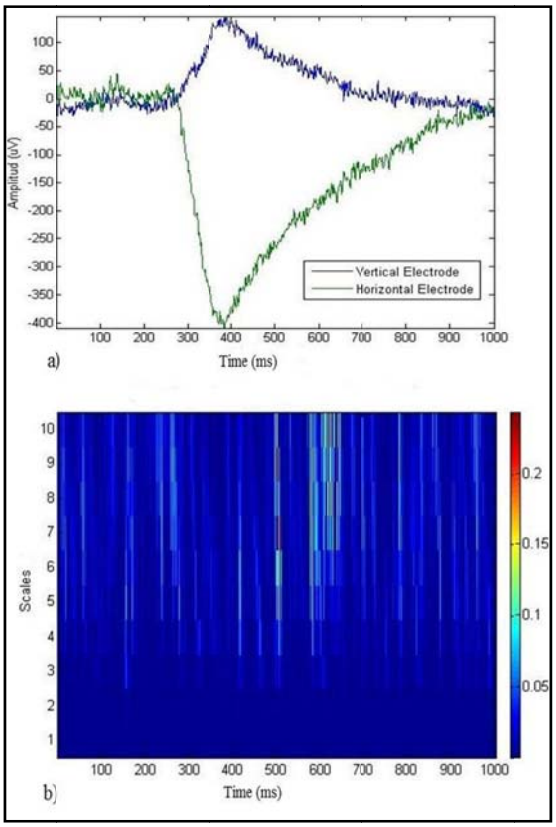
It was then uploaded into a program that runs a wavelet scalogram in order to present the signal in the wavelet coefficient energy in scale and space or time. The signals is decomposed down to 10 level of details using Daubechies order 4 (db4) as a mother wavelet. The db4 has been chosen because it has two vanishing moment, i.e. constant and linear component. The numbers of level decomposition strictly depend on the sample rate of original signal recorded.

IV. RESULTS AND DISCUSSION

When it comes to the time frequency analysis in wavelet transform, we are interested in knowing the distribution of signal energy of wavelet details coefficient with the change of time. Hence, we plotted a scalogram for each movement in order to identify the dominant scales over the maximum wavelet energy coefficient for the signal. The scalogram is used because it represents the time frequency localization property of wavelet transform. In this plot, each details coefficient is plotted as a filled rectangle whose colors correspond to the magnitude of the coefficient. The bar on the scalogram plot indicates the range of energy for each level. This energy is defined as the sum of the squares of the details coefficient for each scale. Figure 6 and Figure 7 show the scalogram of signals of four different movements from a subject; left, right, downward and upward.

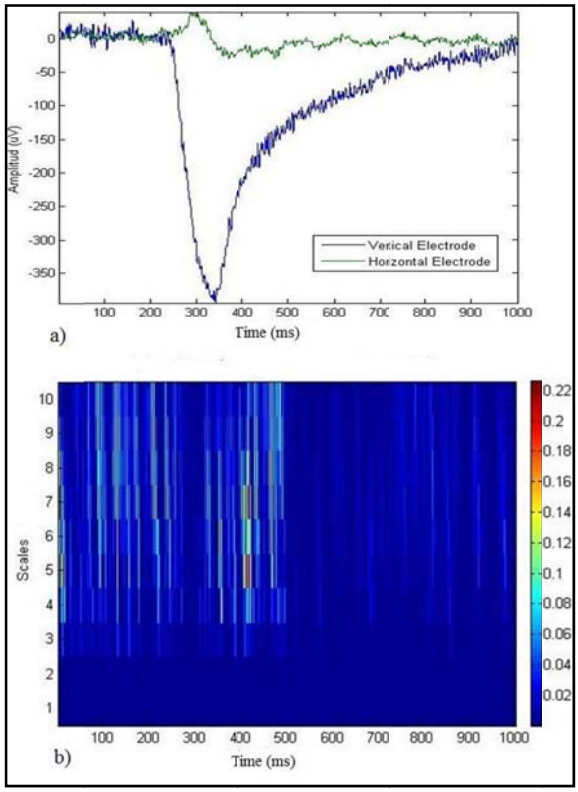


i) Left eye Movement

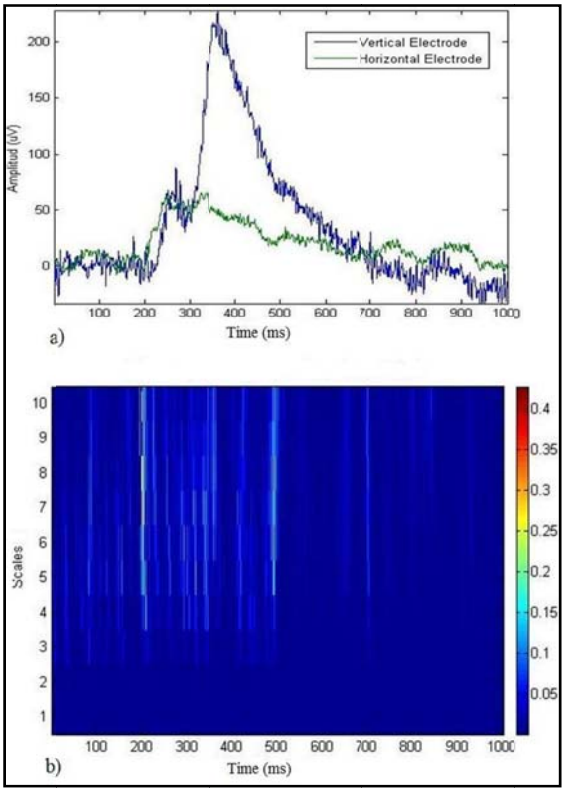


ii) Right eye Movement

Fig. 6. Scalogram of horizontal eye movements



i) Upward eye Movement



ii) Downward eye Movement

Fig. 7. Scalogram of vertical eye movements

The scalograms reveal that highest energy of the signals is captured in the different scale of details coefficient for different EOG signals. Frequency component extracted by details move from high frequencies to low frequencies as scale of wavelet coefficient increases from 1 to 10, with frequency content being halved at each increment in accordance to the sampling rate which is 1000 Hz (see Table I).

About 15 data for each eye movement have been analyzed by using wavelet scalogram in order to extract the most dominant energy details coefficient and it frequencies. The number of extracted detail coefficients from each level is calculated and plotted as shown in Figure 8. From Figure 8, it is noticed that the average percentage for each movement data is slightly different from their energy level. This means that different eye movements are associated with different frequency bands.

The percentage of each detail coefficient of four eye movements is illustrated in Figure 8. Statistically, the dominant energy is: scale 6 for left eye movement; scale 7 for upward; scale 8 for right and scale 9 for downward. They are summarized in Table II.

Dominant energy level means the maximum details coefficient energy that can be derived by scalogram for each signal. We use this parameter as the benchmark to classify the different movement of EOG signals.

SCALE	FREQUENCY RANGE (Hz)
1	250-500
2	125-250
3	62.5-125
4	31.25-62.5
5	15.6-31.3
6	7.8-15.6
7	3.9-7.8
8	1.9-3.9
9	0.9-1.9
10	0.5-1.0

Table 1: Frequency Content 10 Level Decomposition

EOG Signals	Dominant Energy Scale	Average Percentage (%)	Estimated Frequency
Left	Scale 6	80.0	8-16 Hz
Right	Scale 8	98.2	2-4 Hz
Up	Scale 7	99.2	4-8 Hz
Down	Scale 9	95.4	1-2 Hz

Table 2: Dominant energy level for 15 EOG Data

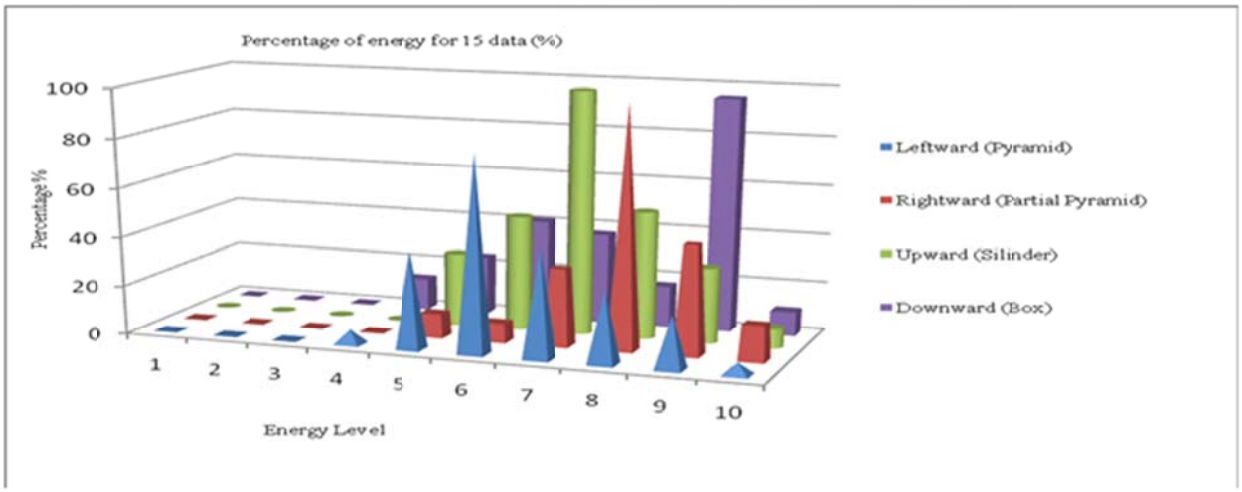


Fig. 8: Average percentages of energy level for 15 data of vertical and horizontal eye movements

V. CONCLUSION AND FUTURE RECOMMENDATIONS

This study has classified each EOG signals movement based on its estimated frequency using wavelet scalogram decomposition. This is different to previous studies in which they only focused on the overall wavelet decomposition and not specifically into the details of each EOG signals of each frequency bands. Hence, this paper proposes and targets the researcher to look into details of the energy and frequency bands distribution within four eye movement signals for better interpretation of EOG signals analysis by using wavelet scalogram. Result obtained indicates that each eye movement has different frequency bands and could be integrated to design a support machine for paralyzed people to move their wheelchair by using eye movements.

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Test Case Generation using GOM Algorithm

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***Abstract*—Software testing involves appropriate validation and verification of a software component developed during the software lifecycle. Usually testing costs often account to high budget in the software development process. In order to minimize the testing costs, researchers and practitioners automate the testing process rather than carry out manual testing. Test Case Generation is the process of automatically generating a collection of test cases which are applied to a system under test. This paper utilizes branch coverage criteria using the Generalized Optimization Meta heuristic (GOM) algorithm and code constraint graph (CCG) to efficiently maximize the coverage of all the branches. The experimental results show that the proposed test generation technique is effective in generating tests for an application at large.**

***Index Terms*—Test case generation, branch coverage, evolutionary algorithm, Code Constraint Graph**

I. INTRODUCTION

Testing is the process of exercising a software component using a selected set of test cases, with the intent of revealing defects**.** Testers need to detect these defects before the software becomes operational. Automating the testing process is a relevant issue since it will help reduce analysis costs by enabling a more systematic approach to testing [1]. A good test case is one that has a high probability of revealing a yet undetected defect. It requires the tester to consider the goal for each test case, that is, which specific type of defect is to be detected by the test case. Test Case Generation (TCG) is the process of automatically generating a collection of test cases which are applied to a system under test [28]. White-box TCG is usually performed by means of symbolic execution, i.e., instead of executing the program on normal values (e.g., numbers), the program is executed on symbolic values representing arbitrary values [9]. Test cases should be developed for both valid and invalid input conditions. That is, a tester must not assume that the software under test will always be provided with valid inputs. Inputs may be incorrect for several reasons. For example, software users may have misunderstandings, or lack of information about the nature of the inputs. A test case must contain the expected output or result and the results of the tests should be inspected meticulously. Branch coverage testing criterion encounters all the branches in a program i.e., the predicate of an 'if' statement should be evaluated to both true and false. The stronger criteria of condition, multiple-condition and path coverage are often infeasible to achieve for programs of more than moderate complexity, and thus branch coverage has been recognized as the basic measure for testing.

A small number of test-data techniques have already been automated: random, static and dynamic, analysis-oriented, goal-oriented and structural or path-oriented test-data generators. Random generator is the simplest method of generation techniques, creates large amounts of test data; it could actually be used to generate input values for any type of program. Ultimately, a data type such as integer, string, or heap is just a stream of bits. However, because no information exists about the testing objectives, the generators often fail to find data that satisfy the stated objectives of the testing process. Since it merely relies on probability it has quite low chances in finding semantically small faults, and thus accomplishing high coverage. A semantically small fault is such a fault that is only revealed by a small percentage of the program input. Static and dynamic generators execute a program symbolically by means of variable substitution techniques instead of actual values. This technique requires plenty of computer resources. It also puts a lot of restrictions on the program. Symbolic execution also implies that a symbolic evaluator for the particular language is built which indeed requires a great amount of work. XML is now being used to replace large relational databases. Therefore, performance testing of XQuery implementations on very large documents is important [4].

Analysis-oriented generators have the ability to generate high quality test-data, but rely upon their designer with a great insight into the domain of operation, and hence are not readily extrapolate to arbitrary software systems. Goal-oriented generators provide guidance towards certain set of paths. Instead of letting the generator generate input that traverses from the entry to the exit of a program, it generates input that traverses a given unspecific path [11]. Because of this, it is sufficient for the generator to find input for any path. Two methods using this technique have been found: the chaining approach and the assertion-oriented approach. The latter is an interesting extension of the chaining approach. Typical for the chaining approach is the use of data dependence to find solutions to branch predicates. The characteristic of chaining is to identify a chain of nodes that are vital to the execution of

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the goal node. This chain is built up iteratively during execution. Since this method uses the find-any-path concept it is hard to predict the coverage given as a set of goals. Assertion-oriented testing truly utilizes the power of goal-oriented generation. Certain conditions, called assertions are automatically inserted in the code. When an assertion is executed it is supposed to hold, otherwise there is an error either in the program or in the assertion. But they have serious problems associated with failing to find the global minima. The search space tends to 'lack features' and consists of large 'flat' areas which provide no information on the location or the direction of the true local minima. Although a number of different goal-oriented approaches and algorithms exist, it is difficult to judge exactly which approach represents the current state of the art. Structural or Path-oriented generation identifies the path for which the test data is to be generated. Unfortunately, if the path is infeasible that would cause the generator to fail to find an input that will traverse the path. Even though it has the merit of very thoroughly testing a specific path, it has two severe disadvantages. The first is that the number of paths is exponential to the number of branches. The second is that many paths are impossible to exercise due to relationships between the data. Branch coverage criterion measures which decision outcomes of an 'if' statement have been tested. Determining the number of branches in a method is also easy. The total number of decision outcomes in a method is hence equal to the entry branch in the method plus the number of branches that need to be covered.

The rest of this paper is organized as follows. Section 2 discusses research related to the related work. Section 3 presents the details of the proposed approach. Section 4 describes an experimental study of the proposed criterion and observations. Section 5 presents conclusions and future work.

II. RELATED WORK

The work of M.F Bashir, and S.H.K. Banuri, [1] extends the paradigm of the test data generation system to incorporate both specifications and model based testing which helps to perform the reclassification of the code, specification or model based techniques. Several attempts have been made to develop a system to generate test data automatically. The existing such system does not guarantee to generate test data in only feasible paths. Praveen Ranjan Srivastava et al. [2] proposed a method to generate feasible test data, using Genetic Algorithm. It is often desired that test data in the form of test sequences within a test suite can be automatically generated to achieve required test coverage. The work of Sushil K. Prasad et al. [3] proposes Genetic algorithm to test data generation for optimizing software testing. Ana Barbosa et al. [5] proposed a test case generation approach to model-based testing of graphical user interfaces from task models. [5] shows how task mutations can be generated automatically, enabling a broader range of user behaviors to be considered. More recently, Grammar-based test generation has been applied to many other testing problems, including the generation of eXtensible Markup Language (XML) documents and the generation of packets for testing communications protocols [6].

Recent research has shown how to integrate covering-array techniques such as pairwise testing into Grammar-based test generation tools [6]. Their work proposed two case studies showing how to use grammars and covering arrays for automated software testing. Valentin Dallmeier et al. [7] combined systematic test case generation and typestate mining, static typestate verifier fed with enriched models report significantly more true positives, and significantly fewer false positives than the earlier proposed models. [8] proposed an automatic test generation solution using dynamic symbolic execution, uses distance in control-dependency graph to guide path exploration towards the change. [8] is effective in generating change-exposing inputs for real-world programs. [9] proposed a symbolic execution mechanism, by developing a fully Constraint Logic Programming based framework for test case generation of an OO imperative language. Rafael Caballero et al. [10] presented a general framework for generating SQL query test cases using Constraint Logic Programming. [11] presented an automated approach to generate unit tests that detect these mutations for object-oriented classes, the resulting test suite is optimized towards finding defects rather than covering code and the state change caused by mutations induces oracles that precisely detect the mutants. [12] proposed an approach for automated test case generation based on techniques from constraint programming. [13] proposed a scalable toolset using Alloy to automatically generate test cases satisfying T-wise from SPL models. [13] defines strategies to split T-wise combinations into solvable subsets.

III. OVERVIEW OF THE APPROACH

A. Framework

The block diagram of this proposed approach is depicted as in Fig.1. It consists of a three-tier architecture containing the following four blocks: Source code analyzer, XML parser, Constraint analyzer and Test data generator. Initially, a sample code consisting of only 'if-else' constraints is taken as input. As the name 'constraint' specifies, the input code that is to be tested should never contain or be allowed any loops such as 'while' or 'for' loops. The *source code analyzer* block analyses the input code and generates an XML document which separates the constraints and their outcomes and also neglecting the statements if any, present. The *XML parser* block initiates the XML document and creates a notepad file containing the constraints similar to those present in the XML document, given as the input file to the algorithm employed i.e., the evolutionary meta-heuristic algorithm. The primary portion of the third block which is the *constraint analyzer* takes the notepad file generated earlier as input and generates a graph called the Code Constraint Graph (CCG). This graph indicates the program flow of the source code as to which branches are present and which are to be tested. The CCG is no longer used because it just shows the control flow of the input source code. The secondary portion of the third

block called the *test data generator* block implements the evolutionary algorithm namely the Generalized Optimization Meta-Heuristic (GOM) algorithm, which takes the notepad file to be checked against the constraints separated.

The test data generator block first generates a random set of integers which may range from positive to negative. The set may contain an approximate number of 40-50 random integers. For each of the random set of integers, a fitness formula is evaluated in order to advance to the next population. After calculating the fitness for each of the random set of integers, fitness values are assigned to them. The chromosome with the optimal fitness is chosen as the base chromosome for the next generation of members. Each chromosome contains 24 bits. So the 24 members of the next population are generated from the base chromosome by flipping each bit of it. Those newly generated members are then calculated by the given fitness functions. Then the chromosomes are ranked according to their fitness values, from worst to the best. The optimal chromosomes of the next and the previous population are compared. The population that has a comparatively lesser optimal chromosome is deleted and the other one is kept as the base chromosome for the generation of the members of the next population. Cross over and mutation operations are applied to them if necessary.

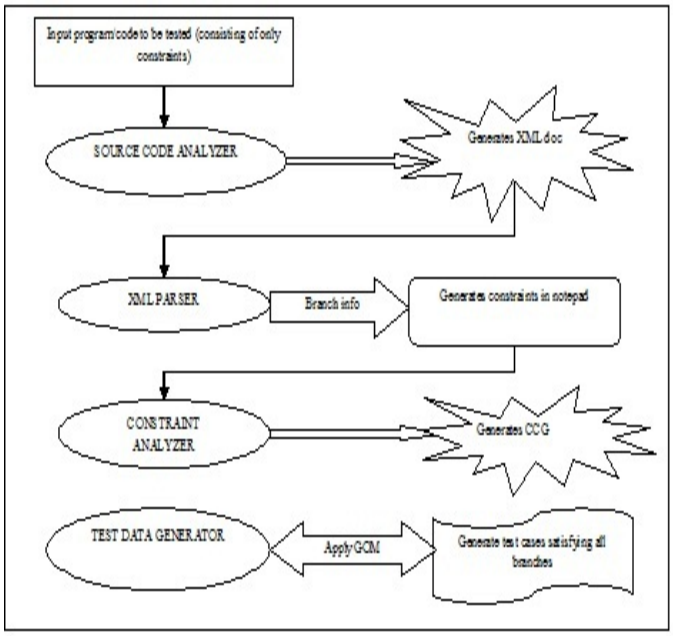

Fig. 1. Proposed Framework for test case generation

B. Motivational Example

Consider the triangle classification program in Fig. 2, which accepts three variables say A, B and C each for the three sides of a triangle. The triangle classification accepts three integers as the three sides of a triangle, and decides which type of triangle it based upon the length of these three slides. The four possible results are: scalene, isosceles, equilateral and not a triangle. If all the three sides are equal, the program returns an equilateral triangle. If any two sides are equal, the program returns an isosceles triangle. If none are equal, then the program returns a scalene triangle. So in this algorithm the above procedure of ranking and cross-over mutation operations are repeated three times, i.e., each for three sides of a triangle A, B, C. The generated members of the first population contain the chromosomes each with three genes that indicate the three variables used in that program. Every chromosome is then passed to the notepad file and checked against the constraints. When the chromosomes passed satisfy the particular constraints, a counter variable is incremented so as to count the number of branches satisfied by them. This procedure is repeated for each chromosome of the first population. After completing all the members of the first population, the same operations are performed for each pair of genes and then by applying cross over and mutation operations. The above procedure is repeated till the maximum number of branches is satisfied by the branch coverage criterion. The GOM algorithm generates three genes in each chromosome, as the number of variables involved in the source code is three. Before the generation of the appropriate genes in a chromosome, the program module is first parsed and all the 'if-else' branches involved are separated in a notepad file in order to easily give input to the GOM algorithm.

```
int triType(int a, int b, int c) {
 1   int type = PLAIN;
 1   if (a < b)
 2     swap(a, b);
 3   if (a < c)
 4     swap(a,c)
 5   if (b < c)
 6     swap(b, c)

 7   if (a == b) {
 8     if (b == c)
 9       type = EQUILATERAL;
 .     else
10       type = ISOSCELES;
 .   }

11 else if (b == c)
12   type = ISOSCELES;
13 return type;
}
```

Fig. 2. Module of triangle classification.

C. Formulation of branch coverage

The proposed approach in this paper utilizes branch coverage criteria using a Generalized Optimization Meta heuristic (GOM) algorithm and code constraint graph (CCG). The process of generating test cases using GOM algorithm and CCG graphs is as follows; assume the input that is to be checked against the constraints in the source code to range *I* as: $\{I_1, I_2, \ldots, I_n,\}$. Define and identify the test constraint set C as: $\{C_1, C_2, \ldots, C_m\}$. For each and every input I, the test cases (*Tc*) are generated so that those inputs must satisfy the appropriate constraints encountered in the constraint set and this process is repeated until the maximum branch coverage is attained as output for the given input set. The amount of branch coverage (T_{bc}) criterion can be expressed mathematically as:

$$T_{bc} = (BC + SC + MC / 2 \times B + S + M) X\ 100$$

$$FITNESS = 100 - T_{bc}$$

Where *BC* - number of branches covered
SC - number of statements covered
MC - number of methods covered

B – Total number of branches
S – total number of statements
M – total number of methods

The steps to be employed are as follows:

- A sample input code containing 'if-else' constraints is taken as input.
- The constraints present in the source code are separated by reading line by line and the unnecessary statements, header files, braces and new lines are removed.
- The GOM algorithm is employed after generating a random set of integers say, up to 40-50 iterations.
- The test cases are generated by the GOM algorithm indicating which branches are covered by appropriate chromosomes, each containing three genes.
- The percentage of branch coverage by the chromosomes is obtained by applying the relevant formulas regarding the branch coverage.
- The highest percentage of coverage by the chromosomes is returned as the best solution.

D. Proposed pseudo code of the algorithm

Fig. 3 depicts the pseudo code of a Generalized Optimization Meta-Heuristic (GOM)

Procedure TDGen
Input:
Program: code/program under test
Output:
CCG: A code constraint graph, which shows the control flow of the source code.
Test cases: A set of test cases that is generated using GOM algorithm.
begin

1. A sample code consisting of "if-else" conditions is taken as input.
2. The source code analyzer generates an XML document by analyzing the constraints in the source code and separates them in that document.
3. The XML parser goes through the XML document created and creates a notepad file containing only constraints so as to easily give as input against the GOM algorithm.
4. The constraint analyzer accepts the notepad as input and generates a tree called Code Constraint Graph (CCG) so that it shows a program flow of the source code with constraints as which branches are present and that are to be tested.
5. For each entry of the requirements. Initialize randomly the population of S species (bits) that are used to encode D program variables.

loop

- *For each of the S bits of the species, find the fitness value.*
- *Find the base chromosome that has the best fitness among the generated members.*
- *Generate first population using bit changes to the base chromosome, as much times as its bits.*
- *Evaluate the first population against the fitness function to find the fitness value, and assign to each of the members.*
- *Perform ranking operation to rank the members according to their fitness value.*
- *Apply either "one-point" or" two point" cross over operation by taking either best and its successor or worst and its predecessor.*
- *Modify a single bit of the gene with probability* $P \alpha k^{-\mu}$ *(where k is the rank of the bit and μ, a free control parameter)*
- *Compare the first population and next population fitness values. Discard the population which has worst base chromosome.*
- *Repeat the above procedure for next population.*
- *Update branch coverage criteria, test cases and iteration counter.*

until stopping criterion is met

6. Return the branch coverage result and test cases.

end

Fig. 3 Generalized Optimization Meta-Heuristic (GOM) pseudo code

Separation of constraints from the source code: The source code itself cannot be tested since it has irrelevant codes such as printing statements, other logical statements, etc. So it is necessary to separate the constraints alone from the source code, in this case the branches with their appropriate outcomes i.e., children. The methodology used to separate the branches alone from the source code consists of reading each and every line of the source code until a branch or constraint is encountered. A better way to implement this methodology is to read the source code and place them in an XML document. As seen in Fig. 1, the source code analyzer block performs this operation. As the branches are separated in that XML document, the unnecessary new lines, braces and other header files are removed so that only the constraints are filtered. The generated XML document is parsed and the appropriate operations are performed so that the unnecessary codes are removed. As seen in Fig.1, the XML parser block performs this operation. The filtered branches are placed in a notepad file, given as input to the GOM algorithm. In the notepad, an @ symbol is referenced before each branch so that a constraint is encountered. If any children's are present in a branch, the @ symbol is incremented and if the line comes outside the 'if-else' branch, the @ symbol is appropriately decremented. The generated filtered branches and/or constraints from the source code are visualized as in Fig. 4 as:

```
enter tritype
@if(a<b)
@@swap(a,b);
@if(a<c)
@@swap(a,c);
@if(b<c)
@@swap(b,c);
@if(a==b)
@@if(b==c)|
@@@type=eqilateral;
@@else
@@@type=isoceles;
@elseif(b==c)
@@type=isocesles;
@return type;
```

Fig. 4 Sample constraint generation

Generation of Code Constraint Graph (CCG): The Code Constraint Graph can be generated from the notepad file created as in Fig.3 to show the control flow of the source code consisting of constraints. As in fig. 1, the constraint analyzer block performs this operation of generating the CCG. The sample CCG generated from the triangle classification module can be visualized as in fig. 5 as shown below:

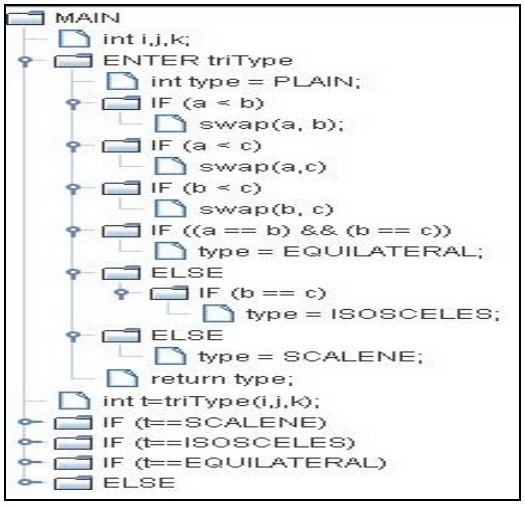

Fig. 5. CCG generation

Generating test cases using proposed evolutionary algorithm: The proposed Generalized Optimization Meta Heuristic (GOM) algorithm is a type of an evolutionary algorithm (EA) that makes use of evolutionary [16, 17] strategies (ES) and evolutionary programming (EP). The main idea behind the EAs is to evolve a population of individuals (candidate solutions for the problem) through competition, mating and mutation [18], so that the average quality of the population is systematically increased in the direction of the solution of the problem at hand. The evolutionary process of the candidate solutions is stochastic and "guided" by the setting of adjustable parameters. In an analogy with a natural ecosystem, in a EA different organisms (solutions) coexist and compete. The more adapted to the design space will be more prone to reproduce and generate descendants. On the other hand, the worst individuals will have fewer or no offspring. In an optimization problem, the fitness [19, 20] of each individual is proportional to the value of the objective (cost) function, also called fitness function.

In a GOM algorithm, each bit is considered a species and a string of S bits is taken as the initial population of the species. The string consisting of S bits then encodes the D program variables to be represented in a binary format of 0's and 1's. In a variation of the canonical GOM described above, the bits are ranked separately for each substring that encodes each program variable, and N bits, one for each variable are flipped at each iteration of the algorithm. First, the GOM algorithm generates the random integers of up to 40-50 numbers. From the generated random numbers, each and every two pair of integers is taken into account. The second number of the pair is taken and the bits of that number are ranked according to their priority. The highest and the lowest bits are taken as an average to obtain a result. In the first number of the pair the shifting operation is performed, as many times as the result of averaging. The same procedure is repeated for the second number and the modified first and second numbers are kept aside. Then these numbers undergo appropriate cross over and mutation operations. The cross over method used here is the "two point" cross over.

The mutation operation is then performed with respect to the probability $P \alpha k^{-\mu}$, where k is the rank of the bit and μ, a free control parameter. These optimized integers are then checked against the notepad file generated earlier. When the chromosomes satisfy a particular branch, a counter variable is incremented which indicates the number of branches that are satisfied by a single chromosome. In this case, a single chromosome consists of three genes since the number of variables encountered in the triangle classification is three namely A, B, C. The above procedure is repeated till the chromosomes in all populations by means of branch coverage criteria cover a maximum number of branches. The general representation of two-point cross over can be represented as: The two point crossover operator takes two vectors $(a_1,\ldots, a_n)$ and $(b_1,\ldots, b_n)$ and yields two vectors $(a_1,\ldots, a_i, b_{i+1},\ldots, b_j, a_{j+1}, \ldots\ldots, a_n)$ and $(b_1,\ldots, b_i, a_{i+1},\ldots, a_j, b_{j+1}, \ldots\ldots, b_n)$, where $1 \leq i < j \leq n-1$ and i and j are randomly chosen. This means that both vectors are split at the same two positions and assembled with swapped middle parts. An example of a mutation operation performed is, Before: 1 1 0 1 1 0 1 0 0 1 1 0 1 1 1 0, After: 1 1 0 1 1 0 0 0 0 1 1 0 1 1 1 0, a change of bit in the gene takes place at bit position 6.

IV. THE EXPERIMENT

A. Subject Programs, Faulty Versions, and Test Case Pools

To examine the efficacy of our approach, the proposed approach was evaluated using real-world programs. In this section, we report the empirical evaluation results. We compared the GOM Coverage with the GA Coverage. In the experiments, the Siemens suite programs (Table 1), similar to those used by Dawei Qi et al. [8] and Rothermel et al. [15] were used to validate the performance of the proposed approach. Each program was hand-instrumented to record all the coverage information. Each program has a variety of

versions, each containing one fault. Each program also has a large universe of inputs. We obtained the subject programs from the Software-artifact Infrastructure Repository at UNL [14].

TABLE I
SIEMENS SUITE SUBJECT PROGRAMS

Name	Lines of code	Faulty version count	Test pool size	Program Description
tcas	162	41	1608	Altitude separation
totinfo	346	23	1052	Information measure
schedule	299	9	2650	Priority scheduler
schedule2	287	10	2710	Priority scheduler
printtokens	378	7	4130	Lexical analyzer
printtokens2	366	10	4115	Lexical analyzer
replace	514	32	5542	Pattern replacement
Space	9127	38	13,585	Array definition language interpreter

B. *Experimental Results and Observations*

To examine the efficacy of our approach, we evaluated our approach using real-world programs. In this section, we report our empirical evaluation results. The obtained results of branch coverage criteria can be depicted by a graph as in Fig. 6 showing the convergence of coverage. The number of iterations is scaled along the X-axis and the percentage of branch coverage is scaled along the Y-axis. As compared to the simple genetic algorithm, GOM algorithm converges faster in less number of iterations. The maximum branch coverage obtained by applying the proposed algorithm is nearly 71%. As seen in Fig. 6, the applied GOM algorithm converges at a faster rate than the simple genetic algorithm i.e., at iteration 70 (number 7), the GOM reaches the maximum branch coverage of 71% and it is consistent in the further numbers of iterations, whereas the genetic algorithm reaches the maximum branch coverage of 64% only at iteration 100 (number 10).

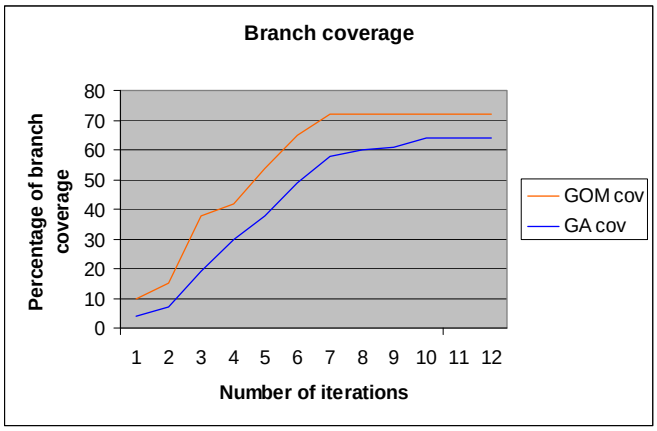

Fig. 6. Comparison of branch coverage of GA and GOM

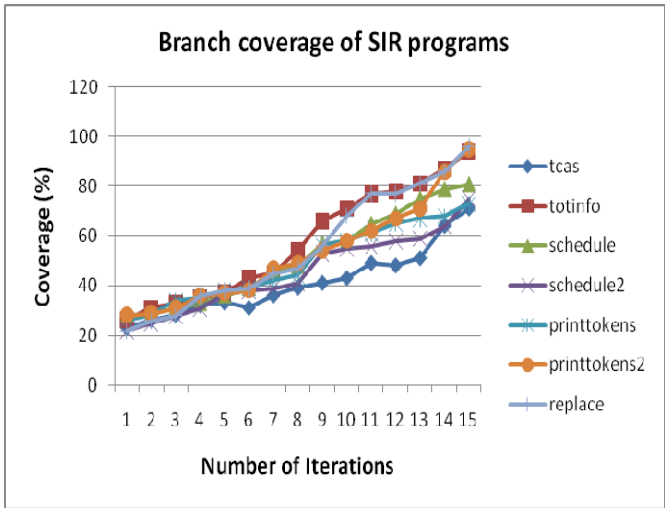

Fig. 5. Branch coverage of SIR objects

Fig. 7 shows the Branch coverage of the SIR objects. In terms of numbers, the vast majority of all test cases have at least one assertion. Although the achieved score is quite high, the search based approach offers potential for optimization. While the coverage based impact measurement guides the search towards assertions, in the experimental of SIR programs, for certain cases GOM is fair in coverage.

V. CONCLUSIONS AND FUTURE WORK

The GOM algorithm implemented gives a suitable way for automatic test case generation. The ease of test case generation is faster than with the simple genetic algorithm since the number of iterations for reaching the optimal solution is quick. The separation of constraints from the source code and then exporting them to a separate notepad file makes the implementation of this algorithm further easier. The code constraint graph (CCG) generated allows understanding the control flow of the source code to depict the amount of statements, branches and methods present and also which are covered. The cross-over and mutation operations are optional, since the algorithm has the capability to converge well without performing those operations. In terms of future work, we can extend our method by improving the fitness function to

deduce a better result above the maximum amount of coverage obtained.

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A Review of Existing Traffic Jam Reduction and Avoidance Technologies

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***Abstract*—Traffic congestion has become a growing problem in many countries since the innovation of engines, and consequently, the mass production of commuter vehicles in the 19th century. A number of solutions have been sought to reduce its impact. Through a literature survey, this paper attempts to categorize a number of current approaches and identify the strengths and weaknesses of each solution or a combination of such solutions, in order to build a good background study. From this survey it has become clear that for success any solution most likely will have to integrate technologies from the different categories. For example, technical solutions must be combined with good traffic rules and regulations. Public education and the announcement of new regulations for commuters must be performed in stages and repetitively to increase public awareness.**

***Index Terms*—traffic jam avoidance, congestion, integrated and intelligent system.**

I. INTRODUCTION

CURRENTLY there are numerous problems associated with traffic jams. Aside from the delays that a traffic congestion may cause, it can also affect people psychologically (in terms of stress) as well as physically (causing tiredness, accidents, noise pollution and breathing problems due to air pollution). Traffic jams can be caused by obvious factors, such as the overflow of vehicles during busy hours or at special events, accidents, slow vehicles obstructing fast lanes, etc. and also by not so obvious reasons like (i.e. ripple effect which causes phantom traffic jams [1]).

Many researchers have offered various approaches to tackle the traffic jam problem. The cost to reduce its impact has also been growing, which makes many developing countries lag behind in their effort to overcome it. For example, in 2003 to 2004 alone Great Britain [2] has spent 242 million pounds to start its *Making Better Use* (MBU) program, which is part of its Highway Agency program. This program includes (but not limited to) the installation of automated incident detection and warning system, CCTV cameras, advanced road side message signs, spot improvements on needed areas (such as improving layouts of lanes and junctions and signaling at various junctions), finding novel approaches to traffic management and the management information systems necessary to support the agency's work, as well as research and development of a national traffic control center.

Each approach can use one particular technology or a combination of them. A couple of common technologies used in many relatively advanced countries are ETC (Electronic Toll Collection) which was started in 1986 in Norway, and VICS (Vehicle Information and Communication System) which was started in the 1990s in Japan [3]. ETC allows drivers to pass a toll gate without stopping for payment and is installed in many cars. The VICS system [16] is a service using FM broadcast and optical beacons on the roadside to deliver traffic jam information to drivers so that their car navigation systems can display congested areas/roads on the map and navigate them avoiding the congested areas. Both systems can reduce the possibility of traffic jams, but requires supporting devices on the roads and on each vehicle. The ETC method not only requires a device on each vehicle, but it also assumes that each vehicle owner abides by the regulation; otherwise the automatic bank-account deduction mechanism will not work. Additionally, there is the extra cost incurred when the authorities want to persecute negligent vehicle owners.

Similarly in the VICS system, although VICS is useful there could be a time lag between the disseminated information and the real situation faced by the driver. This is because VICS collects all traffic jam information to one location (e.g., a central server), and disseminates it after processing. Also, if all cars in a certain road receive the same information and change their route in the same way according to the information, then the selected route will be congested quickly. Additionally, VICS requires many devices to be installed on the roadside for monitoring traffic conditions, and thus it is costly to deploy the VICS system on small roads (which can be used as alternative routes during a traffic jam). The cost is even higher when considering coverage for a large metropolitan city.

II. RESEARCH & REVIEW METHOD

This paper attempts to categorize a number of current approaches, as well as identify the strengths and weaknesses of each solution or a combination of solutions. The aim is to build a good background study, before proposing new ideas. The method used is through a literature survey. The survey

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includes browsing about this topic in the internet and in IEEE's digital library, as well as looking in to a number of books.

III. A NUMBER OF APPROACHES IN TRAFFIC CONGESTION REDUCTION

Three approaches are surveyed in this paper. Namely, the approach which is: a) based on meticulous traffic design [2], [5]-[6], [9] and [6]; b) using inter-vehicle communication and traffic flow simulators [3], [8], [10], [12]; and c) using road travel time on Variable Message Signs (VMS) [7], [14]-[15].

A. Meticulous Traffic Design Approaches

The meticulous traffic design approaches involves steps such as regional traffic planning, intersection optimization design, pedestrian crossing optimization design, and operable management measurement (implementing regulations). These steps have shown to be able to improve urban traffic conditions and ease the traffic jams, such as shown in the case of Wanjiali road, Changsha, China [6].

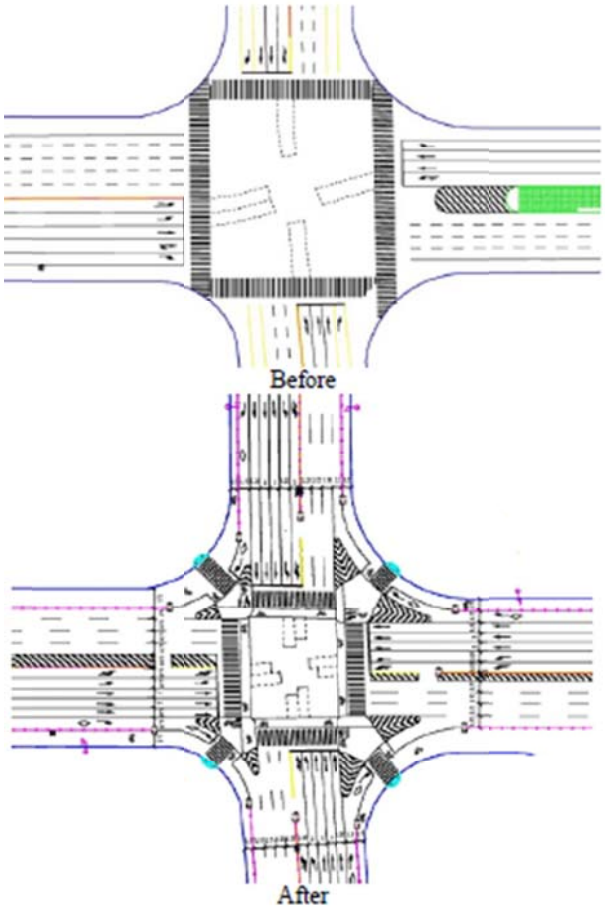

Figure 1: Intersection before and after meticulous design

Research shows that 60% of accidents and most of traffic jams have occurred in intersections [6]. The work of [6] shows that efficiency can be increased by 66.67%, through meticulous transformation design. The transformations includes the reduction of the intersection area, wider left turning wait area, reasonable signal timing, and making the right of way between vehicles and pedestrian clear (see figure 1 and Table 1 [6]).

Another reason for traffic jams is that the number of input-output lanes does not match that in the intersection node. To overcome the over flow of vehicles in the intersection, the center line of the roadway is shifted to reduce the width of the original lanes. The minimum width in single input lane is made to be 2.75m. After a long period of observation, it was noticed that traffic accidents were not increasing and thus this approach was considered to be a feasible solution [6].

Traffic management can also improve the load of the roads, by restricting peak hour traffic through regulation (e.g. applying single-double license plate, and set allowable times, for example during Beijing Olympic Games). Commuters are also encouraged to travel by bus; otherwise they should use the toll road. Tax is applied for privately owned vehicles and other taxes are added, such a mileage tax, a fuel consumption tax, an exhaust emission tax, parking fees and so on. Added to this, parking in the heavy traffic areas is controlled (e.g. limited parking time and limited parking spaces).

Advanced traffic control methods and information technology are usually adopted in meticulous traffic design approaches. This includes making driving route guides and traffic-information available (such as in the VMS system discussed further below), applying managed parking, applying traffic flow control, as well as providing automatic control for public transport.

Other references [2, 5, 9] discuss more regulations and public education, including the following:

(i) Implement employee parking cash-out (equalizing the parking subsidy). This would have an immediate impact of reducing car commuting by 25%.

(ii) Abolish all automobile subsidies (direct and indirect) and pay for this from the gas tax and/or other auto user fees. Similarly, eliminate all "traffic mitigation fees" and "developer fees" and "parking assessment fees" that subsidize the automobile. Alternatively, use these fees for constructing guide way transit instead of automobile-related construction that encourages greater auto use (and make people want to own more vehicles).

(iii) Institute "Fare Lanes." These let anyone use carpool lanes, but charges them a fare per car. Use existing lanes of roads or making better use of motor ways and trunk roads [2]. Do not add more lanes.

(iv) Eliminate parking requirements in industrial areas (and ideally, everywhere). If necessary, implement parking permits for neighborhoods (already common in some cities). Note that this approach will only work if good public transport is available in those industrial areas.

(v) Implement traffic calming to create a more livable neighborhood and decrease automobile dependency. This will also decrease auto usage.

(vi) Use congestion pricing. Any congestion still remaining will be eliminated by the use of congestion pricing. This means charging for road use an amount that varies so that traffic is kept moving. As rush hour approaches, the price increases in stages in order to keep total cars using the facility at the same optimal flow level. The money raised could be used to build guide way transit because road users also benefit by paying for potential motorists to use alternatives. Congestion pricing also increases highway capacity, while reducing political pressure for more highway construction.

(vii) The government (or its appointed agency) should adopt a more expansive approach to testing out the range of measures at its disposal, carrying out more trials at more sites to increase its chances of success, whilst managing the risks involved.

(viii) Before implementing any new road policies the government or appointed agency should seek to educate the commuters or convince users about the benefits they would bring to them, as a means of gaining public acceptance.

Qualitative analysis [2] shows that good design improves intersection traffic capacity and reduces delay, as shown when all the intersection input lanes are changed from 4 to 6, and the number of output lanes is kept invariant. Also, by optimizing open-ends setting, adding signal control, good design is able to eliminate the interference between vehicles and pedestrians, which in turn helps pedestrians cross safely and enables the traffic to flow smoothly. Moreover, quantitative analysis shows that the traffic capacity increases by 15%, delay is reduced by 20%, travel speed can increase by 10%, and conflict point is reduced by 80% [2].

It is clear that the meticulous traffic design approach is very effective, as it combines a number of technologies to reduce the traffic congestion problem.

Step	Improvement
Intersection optimization design	• Increase input lanes by shifting lane center and reducing lane width. • Set pedestrian and bicycles waiting areas by marking / channeling island and railings at corners. • Set left turning waiting area and optimize signal timing.
Open-ends treatment	Close a few open lanes, optimize pedestrian ways, and add signal control at reserved open.
Public traffic	Adjust the station lay-out and improve facilities.
Parking management	Prohibit parking near road-side and across.

TABLE I. Wanjiali road meticulous traffic design [6]

B. Inter-vehicle Communications & Traffic Flow Simulators

Traffic information can be obtained by gathering statistical traffic data using inter-vehicle communication (i.e. short range wireless communication, GPS and small computer in each car) [3]. Consequently the data (the time to get to a certain destination) can be analyzed to detect movement – where slow movement indicates there is a traffic jam. In this method cars are equipped to autonomously collect and share traffic jam information using inter-vehicle communication based on the IEEE 802.11 wireless communication protocol, without using additional devices on the roads. This method allows the onboard device to estimate the time required to get to certain destinations. The steps involved are: (a) measurement of time to pass each route, (b) calculation of the statistics of time to pass each route by exchanging the measured time and statistics among cars, and (c) estimation of time required to get to destination.

Figure 2: Division of traffic into areas (after [3])

In [3] it is assumed that a given road map can be treated as a graph where each node and link corresponds to an intersection and a road between intersections, respectively. The time to get to a destination from the current location of a vehicle can be estimated theoretically by summing up time to pass each link to the destination.

Consequently, a target geographical region can divided into square shaped areas with distances of several hundred meters from one square to another, as shown in Figure 2 [3]. The links through which a car enters and exits an area are called *incoming link* and *outgoing link*, respectively. A pair of incoming and outgoing links is called a *link pair*. Secondly, the time needed to pass each area for every link pair is measured and is called the *area passage time*. The dotted lines indicate boundaries between areas (see Figure 3). As for the area on the center of the figure, there are 5 links across boundary, indicated as α, β, γ, δ, and ε (also Figure 3). When a car passes this area, the car passes two of these links, and thus there are 5 x 4 = 20 combinations of link pairs. When a car crosses boundary of an area, the car records the current time. The area passage time is the difference of recorded time at incoming and outgoing links of the area.

This method was then evaluated using a traffic flow simulator called NETSTREAM, which has been developed by Toyota Central R & D Labs [12]. NETSTREAM was used to

estimate traffic jam at Nagano Olympic Games in 1998 and it was successful in generating a good estimation (i.e. with realistic traffic flows on an actual road system). Moreover, NETSTREAM has the ability to support more than 1000 cars running on a given map simultaneously. It also has a function to construct an arbitrary road system consisting of roads (links), along with legal speed limits and certain number of lanes, intersections (nodes) with traffic lights. It is capable of using specified time intervals to change colors and so on using a graphical interface. NETSTREAM simulates traffic flow on the given map as follows. It reads the map data, the information on links and nodes, and other information such as the time intervals of traffic lights. Its initial information of cars is configurable, along with the number of cars which follows each link or route, and making each car run on the specified link within the legal speed limit. It also records logs including locations of all cars every second. In this simulation experiment up to 300 cars are used. Each car measures the time to pass an area (called area passage time) for each entering/exiting pair of roads (called link pair) of the area, and traffic information statistics are generated from cars which have passed the same pair of roads. By measuring the average area passage time for each pair of roads crossing an area boundary, the time difference between multiple routes with the same link pair can be considered by taking into account also the waiting time at traffic lights and/or turning at intersections. Results show that about 55% of link-pairs time has a difference of less than 10%, which means that this method is accurate enough for practical use [12].

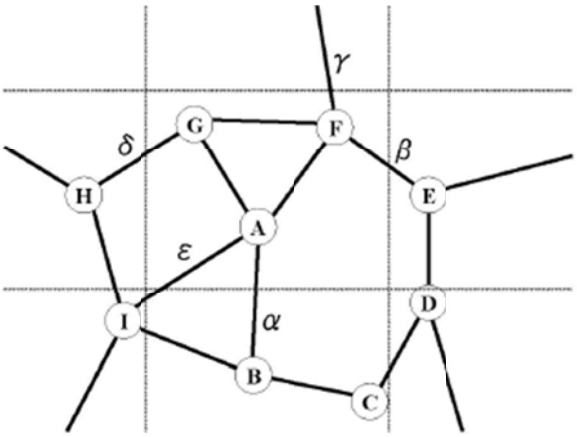

Figure 3: Links across area boundaries (after [3])

Another simulation software currently available is *Legion* for Aimsun [8]. It is a fully integrated pedestrian and vehicle simulation solution which uses mainly video cameras (see Figure 4). Legion has patented its pedestrian simulation solution and its movement algorithms have been calibrated to actual measurements of walking speeds, personal space preferences and the elastic tolerances of these measurements. It claims to have an accuracy of 95% for a prediction of how people will move in spaces and to have been used by independent agencies including London Underground, Madrid Metro and the London Fire Brigade. With Legion the user can evaluate and predict evacuation times, density analysis, journey times between locations, delay, route choice and other metrics. Other prediction software simulations are discussed in [9,10] and [12].

Figure 4: Inside a traffic command centre - video cameras are used in most major cities (after [6, 8])

C. Road Travel Times on VMS

Unlike inter-vehicle communication which uses beacons generated by onboard device on each vehicle, another approach relies on sensors which are embedded on the surface of the road [14]-[15]. These devices can provide data so that drivers can know how much time is required to reach their destination. Integrated with software, this approach helps to improve the flow of traffic according through a self-regulating process: the driving time between two points is displayed in real time, so that drivers can evaluate the state of traffic and may choose another less encumbered route if need be.

Sensors embedded in carriage-ways are able to provide data in order to calculate several variables in real time. This includes data on traffic flow, speed and a representation of traffic density. In the VMS system [7] the other data items suggested to be included in the display (or FM radio) are information on what motorists should consider doing to minimize or avoid delay, alternative routes to help drivers bypass certain congestions (these routes can be suggested more intelligently, using various methods – e.g. ant-colony algorithm [4] or fuzzy algorithm [10]), and relevant information to drivers as they approach junctions to join motorways. These types of information allow drivers to consider other routes, the length of traffic jams and when the jams can be overcome (perhaps due to accidents), and how long it is expected time to clear jams. In the case of ant-colony algorithm, which is applied in North-West region of Delhi, India, consisting of 25 places, it is found that, this

algorithm can provide new routes, resulting in an improvement of distance 3% to 47.9% comparing with existing jammed routes [4].

Figure 5: VMS device (signpost) on the expressway around Paris (Photo. INRETS) [7]

In the VMS system [7] the sensors are typically, spaced approximately 500 meters apart, along with the signposts (see Figure 5) and measurements are taken every minute. Further research by the transportation authorities shows that although drivers are for the most part (98%), glad to benefit from this VMS service, most of the time, they are no more likely to change their itinerary when the expressway is crowded [7], [15]. One study [7], [11] conducted in Paris, France, shows that the assumption that drivers wish to reach their destinations as quickly as possible is not valid for all drivers: out of 30 drivers (all of whom know alternative routes), only 23% of participants emphasized wanting to reach their destination as quickly as possible, and chose an alternative route because they were familiar it; 60% emphasized the comfort of driving; the remaining 17% opted to stay because the travel times to reach their destination displayed on VMS sign board were not too long.

IV. DISCUSSION

From this literature review we believe that the various approaches surveyed can be grouped into three (3) categories. These categories are as follows.

A. Improving the usage of the existing roads or building new ones [6, 9].
B. Installing new hardware:
   i. On the roads: video, sensors [4], [7], [13]-[14], and toll gates (e.g. Electronic Toll Collection [3])
   ii. On each vehicle: devices such as GPS, communication devices (both are usually integrated with software which can include simulations to predict possible traffic jams [8]-[10], [12] and various optimization methods (e.g. ant colony [4])).
C. Implementing regulations which manage traffic [2], [5]-[6].

The applicability of these categories mainly depends on the practicality of implementing each technology used, and the availability of funds. Furthermore, it is clear that there is no single category which can address the traffic jam problem effectively. These categories should be combined in order to free roads from traffic jams. It is also important to implement the most appropriate technology on the most congested roads. For example, the VMS system which requires sensors to be embedded on the target roads cannot be successfully implemented on congested roads which do not have suitable alternatives (capacity and distance wise).

There are number of weaknesses in the approaches surveyed in the current literature review. Certain approaches assume a certain quality of existing infrastructure and assume a certain level of education among the drivers. For example, the meticulous approach of [1] does not recommend building new lanes [9], because the existing lanes are big enough to be converted. In the VMS approach it is assumed that the majority of commuters are keen to read road-messages, which may not be a valid assumption in all deployment situations. Similarly, while certain regulations are practical, others may in fact create additional problems. Thus, for example, regulations prohibiting factory workers to use cars/motors can reduce traffic but its effectiveness is dependent on the existence of good public transportation. Along these lines, regulations imposing too much transport tax in certain countries may cause political unrest. In the case of subsidies, in certain countries subsidies are required to enable funding for infrastructure development. This is notable in developing nations because privately owned companies typically do not have sufficient funds to perform what is seen to be the government's role in infrastructure building.

Overall there are number of promising strong aspects of the various approaches. Many investigations have been conducted in this topic, and these can be used as a stepping stone for other novel solutions in the future, or for the existing methods to mature. Meticulous design has a better chance to succeed since it has combined several technologies and has proven to give good results in achieving better traffic conditions.

V. CONCLUSION

While there are a number of technologies which can aid certain approaches to reduce and avoid traffic jams, there is still a need to look for a solution that makes use of existing technologies (e.g. using existing hardware) in commuter-vehicles. This enables better integration and less cost to the commuters. Using existing technologies also has the benefit of familiarity on the part of the user (drivers), and reduces the need for buyer education regarding the related products. It is also clear that whatever novel solution might subsequently develop, most likely the solution will integrate aspects across the categories of approaches. Thus, for example, in the category of regulations, public education and the announcement of new regulations for the commuters must be performed in stages and repetitively to increase their awareness.

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Analisa Pengaturan Channel untuk Perbaikan Performansi Pengiriman SMS

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***Abstract*—Tujuan studi ini adalah mengidentifikasi teknik pengaturan channel dalam pengiriman SMS yang memungkinkan untuk mengatasi kegagalan pengiriman akibat padatnya traffic channel yang dipenuhi layanan voice pada network CDMA. Diharapkan dengan pengaturan channel pengiriman SMS dapat memperbaiki tingkat keberhasilan pengiriman SMS dan utilitas jaringan CDMA.**

The purpose of this study is to identify channel management techniques for SMS message transmission that can overcome transmission failures caused by high traffic volumes within a voice service in a CDMA network. With the improved management of the SMS channel the desired goal is for a better success rate for SMS message transmissions and for better utilization of the CDMA network.

***Index Terms*— SMS, CDMA, channel, voice, performansi.**

I. PENDAHULUAN

POTENSI pelayanan Potensi layanan SMS (*Short Message Service*) dalam meningkatkan pendapatan operator telekomunikasi dapat terlihat dari usaha yang telah dan selalu dilakukan untuk meningkatkan performansi layanan ini. Segala upaya peningkatan layanan diusahakan agar dapat meminimalisasikan kegagalan proses pengiriman setiap SMS dengan meneliti setiap element network yang bertanggung jawab atas keberhasilan layanan ini.

Data statistik operasional menunjukkan bahwa terdapat peningkatan berarti jumlah kegagalan pengiriman SMS pada jaringan CDMA ketika promosi voice service diberlakukan. Walaupun kegagalan pengiriman SMS ini dapat terjadi karena banyak faktor, namun indikasi padatnya traffic channel yang selalu digunakan oleh voice service menjadi perhatian tersendiri.

Standar pengiriman SMS yang diadopsi oleh operator CDMA di Indonesia merujuk pada dokumen 3GPP2 [1]. Pada dokumen tersebut tidak dinyatakan secara khusus tentang keharusan menggunakan control channel dan traffic channel untuk pengiriman SMS. Keleluasaan ini diberikan pada operator untuk menentukan tipe channel yang tepat untuk melayani karakteristik SMS yang dikirimkan.

Setting length of SMS pada BSC menentukan suatu SMS dikirimkan melalui salah satu dari dua channel tersebut. Sementara setting default setiap BSC didasarkan pada best practice setiap provider, bukan disesuaikan dengan traffic aktual. Sehingga kemungkinan besar terdapat perbedaan besar dalam karakteristik traffic SMSnya.

Paper ini akan mengidentifikasi fungsi pengaturan panjang karakter untuk menentukan pengiriman paket SMS melalui control channel dan traffic channel serta akibatnya pada kegagalan proses pengiriman. Implikasi studi ini adalah untuk mendalami efek pengaturan channel untuk memperbaiki tingkat keberhasilan pengiriman SMS dan utilisasi jaringan CDMA.

II. ALUR PENGIRIMAN SMS PADA SISTEM CDMA

Fungsi utama layanan SMS adalah mentransfer pesan pendek antaran suatu aplikasi yang terletak pada suatu handset atau MS (Mobile Station) and suatu aplikasi dalam network seperti MSC (Message Service Center). MSC dan BSC menyediakan suatu pipa untuk pesan-pesan yang dikirimkan tersebut antara aplikasi yang ada di network, seperti di MC, dan aplikasi dalam handset.

Ada tiga tipe dasar pesan singkat yang didukung pada CDMA system network, yaitu mobile originated point-to-point, mobile terminated point-to-point, and broadcast. Tipe mobile originated point-to-point dan mobile terminated point-to-point membutuhkan mekanisme pertukaran pesan untuk dua arah pada air interface. Studi ini hanya akan membahas layanan SMS Regular yang meliputi SMS Mobile Originated (SMS MO) dan SMS Mobile Terminated (SMS MT) serta tipe-tipe channel yang digunakan untuk melewatkan layanan SMS tersebut.

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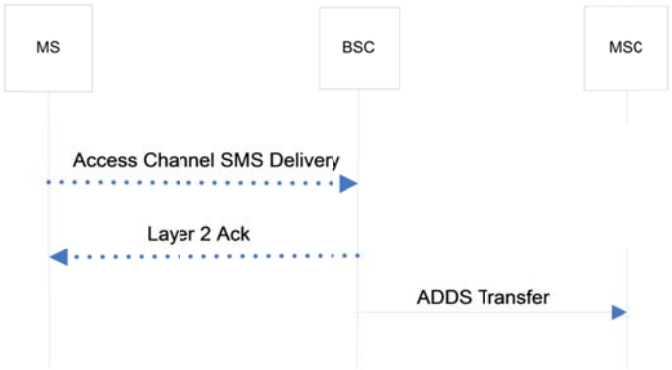
1) Pengiriman SMS MO

Pengiriman SMS MO point-to-point yaitu dari MS ke BSC dapat dilakukan baik melalui control (access) channel maupun melalui traffic channel. Jika pengiriman SMS MO menggunakan access channel, maka selama proses transmisi handset tidak dapat menerima/melakukan panggilan. SMS dikirimkan melalui 'ADDS transfer' dari BSC ke MSC.

Handset/MS mengirimkan SMS ke jaringan melalui access channel. Jika handset meminta acknowledgement layer 2, BS mengirimkan acknowledgement melalui paging channel setelah SMS diterima melalui access channel. Selanjutnya BSC akan mengirimkan pesan 'ADDS Transfer', dimana SMS yang diterimanya dari handset disertakan dalam elemen 'ADDS User Part '.

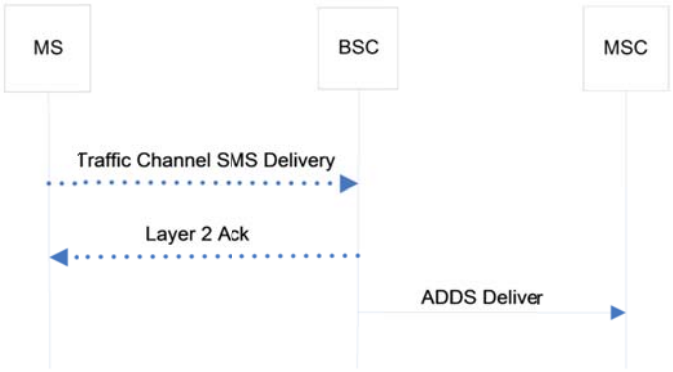
Jika suatu handset sedang menggunakan traffic channel, maka pengiriman SMS-nya akan dilakukan melalui traffic channel yang sedang digunakannya. Sedangkan jika handset yang sedang idle melakukan pengiriman SMS melalui traffic channel, maka handset akan mengirimkan suatu Origination Message ke BSC dengan menyertakan SMS option number pada field service option. Selanjutnya BSC akan mengirimkan 'CM Service Request' ke MSC, dan MSC akan mengirimkan assignment request. BSC akan mencari alokasi resources termasuk traffic channel yang tersedia. Apabila pengalokasian berhasil, BSC akan mengirimkan Assignment Complete ke MSC. Selanjutnya akan terbentuk koneksi dari handset ke MSC untuk pengiriman SMS. Gambar 1 dan Gambar 2 menunjukkan pengiriman SMS MO dengan access dan traffic channel.

Setelah traffic channel terbentuk melalui prosedur sebelumnya, BSC menerima suatu pesan SMS Delivery pada traffic channel dengan tipe burst yang mengindikasikan SMS. Jika acknowledgement layer 2 diminta oleh MS, maka BSC akan mengirimkan acknowledgement ini melalui traffic channel. Selanjutnya BSC mengirimkan pesan ADDS Deliver ke MSC, dimana elemen 'ADDS User Part' diisi dengan SMS yang diterima dari handset.



Gambar 1: Pengiriman SMS MO dengan Access Channel

Setelah traffic channel terbentuk melalui prosedur sebelumnya, BSC menerima suatu pesan SMS Delivery pada traffic channel dengan tipe burst yang mengindikasikan SMS. Jika acknowledgement layer 2 diminta oleh MS, maka BSC akan mengirimkan acknowledgement ini melalui traffic channel. Selanjutnya BSC mengirimkan pesan ADDS Deliver ke MSC, dimana elemen 'ADDS User Part' diisi dengan SMS yang diterima dari handset.



Gambar 2: Pengiriman SMS MO dengan Traffic Channel

2) Pengiriman SMS MT

Sedangkan pengiriman SMS MT point-to-point yaitu dari BSC ke MS dapat dilakukan dengan control (paging) channel ataupun melalui traffic channel.

Untuk pengiriman SMS MT menggunakan traffic channel (Gambar 3) mekanismenya adalah sebagai berikut:

Ketika suatu MSC mengetahui adanya sebuah SMS yang akan dikirimkan ke handset yang sedang menggunakan traffic channel, maka MSC mengirimkan pesan ADDS Deliver yang memuat SMS pada elemen ADDS User Part ke BSC. Lalu BSS mengirimkan SMS tersebut melalui forward traffic channel. Jika BSC tidak menerima acknowledgement setelah mengirimkan CDMA data burst, BSC harus mengirimkan kembali data burst tersebut dimana jumlah pengulangannya tidak boleh melebihi batas maksimum yang telah ditentukan. Jika pengulangan telah mencapai nilai maksimum, maka BSC harus memberikan negative acknowledgement Layer 2. BSC juga harus memberikan pesan ADDS Deliver Ack ke MSC dengan cause value yang bersesuaian dengan kondisi.

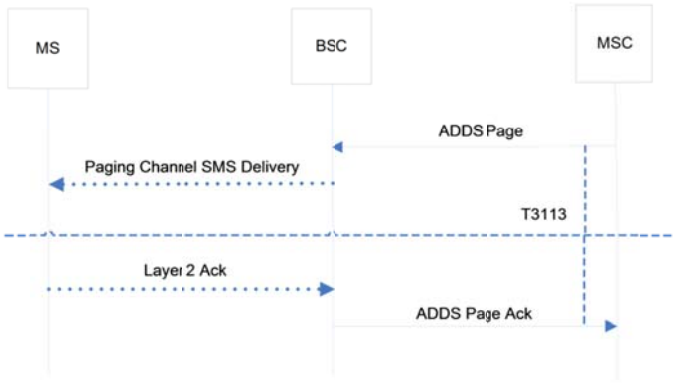
Kemudian handset mengirimkan acknowledgement terhadap SMS yang diterimanya dengan suatu Ack Layer 2. Ketika MSC meminta response dengan memasukkan elemen Tag di dalam pesan ADDS Deliver, BSC harus membalasnya dengan mengirimkan ADDS Deliver Ack dengan elemen Tag di dalamnya setelah BS menerima Ack Layer 2 dari handset.

Sedangkan pengiriman SMS MT menggunakan paging channel terdapat dua metode yang digunakan yaitu tanpa didahului penentuan traffic channel dan dengan didahului oleh penentuan traffic channel.

Pengiriman SMS melalui mekanisme dengan menggunakan paging channel dengan didahului penentuan traffic channel dapat diuraikan sebagai berikut:

Prosedurnya diawali dengan MSC mengirimkan pesan Paging Request ke BS dan timer T3113 mulai diaktifkan. Lalu BSC melakukan paging dengan mengirimkan Page Message

melalui paging channel. Selanjutnya MS membalas dengan pesan Page Response dan BSC mengirimkan pesan informasi Complete Layer 3 yang berisi pesan Paging Response ke MSC. MSC kemudian menghentikan timer T3113. Lalu BSC mengirimkan Base Station Ack Order sebagai acknowledgement dari pesan Page Response dari MS.



Gambar 3: Pengiriman SMS MT dengan Paging Channel

Elemen Radio Environment dan Resources pada pesan Page Response yang mengindikasikan adanya penentuan traffic channel oleh BSC, MSC mengirimkan pesan ADDS Page ke BSC. Dalam rangka melepaskan koneksi transport, BS mengirimkan Release Order ke MS. Lalu MS mengirimkan Release Order ke BS sebagi acknowledgement terhadap permintaan release dari BS.

Selanjutnya MSC mengirimkan ADDS Page ke BSC. ADDS Page membawa SMS dalam elemen ADDS User Part information. Jika MSC meminta acknowledgement, MSC akan memasukkan elemen informasi Tag ke dalam pesan ADDS Page. MSC juga akan mengaktifkan timer T3113.

Kemudian BSC mengirimkan SMS ke MS, yang didahului dengan melakukan prosedur seperti paging ke MS untuk mengetahui di sel mana MS berada. Lalu MS mengirimkan Layer 2 Ack sebagai acknowledgement terhadap SMS yang diterimanya.

Jika MSC meminta acknowledgement dengan menyertakan elemen informasi Tag pada pesan ADDS Page, BSC membalasnya dengan pesan ADDS Page Ack yang menyertakan elemen informasi Tag yang sama nilainya dengan yang dikirimkan MSC. Jika timer T3113 telah diaktifkan sebelumnya, maka timer akan dinonaktifkan.

Sedangkan prosedur pengiriman SMS melalui mekanisme dengan menggunakan paging channel tanpa didahului penentuan traffic channel hampir sama dengan tanpa didahului penentuan traffic channel. Keduanya prosesnya sama sampai pada saat BSC mengirim Base Station Ack Order.

Pada mekanisme tanpa penentuan traffic channel selanjutnya jika elemen Radio Environment dan Resources pada pesan Page Response yang mengindikasikan tidak adanya penentuan traffic channel oleh BSC, MSC mengirimkan pesan ADDS Page ke BSC. ADDS Page selanjutnya membawa SMS dalam elemen ADDS User Part information. Jika MSC meminta acknowledgement, MSC akan memasukkan elemen informasi Tag ke dalam pesan ADDS Page. MSC selanjutnya akan mengaktifkan timer T3113.

Kemudian BSC mengirimkan SMS ke MS, yang didahului dengan melakukan prosedur seperti paging ke MS untuk mengetahui di sel mana MS berada. Lalu MS mengirimkan Layer 2 Ack sebagai acknowledgement terhadap SMS yang diterimanya.

Jika MSC meminta acknowledgement dengan menyertakan elemen informasi Tag pada pesan ADDS Page, BSC membalasnya dengan pesan ADDS Page Ack yang menyertakan elemen informasi Tag yang sama nilainya dengan yang dikirimkan MSC. Jika timer T3113 telah diaktifkan sebelumnya, maka timer akan dinonaktifkan setelah acknowledgement diterima. Kemudian MSC melepaskan semua koneksi transport untuk membersihkan status pending page response.

Dalam rangka melepaskan koneksi transport, BSC selanjutnya mengirimkan Release Order ke MS. Lalu MS mengirimkan Release Order ke BSC sebagai acknowledgement terhadap permintaan release dari BS.

III. DATA DAN METODOLOGI

Data transaksi SMS yang diukur pada network diambil dari beberapa MSC antara bulan Mei sampai Juli tahun 2009 di Jakarta, Surabaya, dan Makasar. Lokasi-lokasi ini dipilih karena terdapat indikasi terjadinya kepadatan traffic SMS yang berlebihan ketika promosi voice service diberlakukan.

Untuk mengetahui tingkat keberhasilan pengiriman SMS pada setiap skenario channel yang berbeda maka dilakukan pengiriman paket SMS dengan jumlah karakter yang berbeda. Proses ini diawali dengan mempersiapkan dua perangkat handset yang bertugas untuk mengirimkan dan menerima SMS. Lalu paket SMS yang dikirimkan akan dipantau dengan memeriksa log setiap node jaringan yang dilewati paket tersebut, yaitu BSC, VLR, MSC, dan SMSC baik yang terjadi dilokasi pengirim maupun lokasi penerima.

Paket SMS yang berhasil dikirim oleh handset pengirim dan tiba di handset penerima kemudian dicacat. Informasi jumlah karakter dan catatan log setiap SMS yang berhasil dikirimkan tersebut selanjutnya dianalisa dengan memperhatikan jumlah karakter SMS yang terkirim terhadap skenario pemilihan channel yang berbeda.

IV. HASIL PENELITIAN DAN DISKUSI

A. Pengiriman SMS MO

Penentuan channel yang digunakan pada pengiriman SMS MO sangat ditentukan oleh setting jumlah karakter terminal pengirimnya. Sedangkan setting jumlah karakter ini bergantung tipe terminal yang ada. Hal ini terlihat pada TABEL 1 yang menunjukkan bahwa dari 5 (lima) terminal terpopuler saat pengambilan data, hanya tipe terminal C yang memiliki setting berbeda. Setting pada terminal C

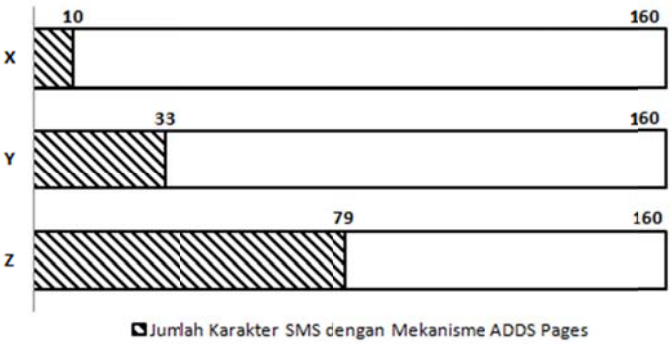
menunjukkan bahwa untuk jumlah karakter sampai dengan 10 maka paket SMS akan di kirimkan melalui access channel. Hal ini berbeda dengan terminal tipe lainnya yang setting pengalihan channelnya pada jumlah karakter 4.

Pengiriman SMS MO menggunakan ADDS deliver mempunyai mekanisme yang kompleks karena diperlukan pendudukan channel. Dari hasil percobaan dengan menggunakan beberapa jenis handset terlihat bahwa perilaku pengiriman dari masing-masing handset berbeda-beda terhadap penggunakan ADDS transfer maupun ADDS deliver.

Namun demikian dari TABEL I, II, III, IV, dan V menunjukkan prosedur mekanisme ADDS transfer lebih pendek dari pada mekanisme ADDS deliver sehingga akan mempercepat proses pengiriman SMS walaupun tidak berarti meningkatkan keberhasilan pengiriman.

TABEL I. JUMLAH KARAKTER SMS DAN CHANNEL YANG DIGUNAKAN PADA PENGIRIMAN SMS MO UNTUK BEBERAPA TIPE TERMINAL

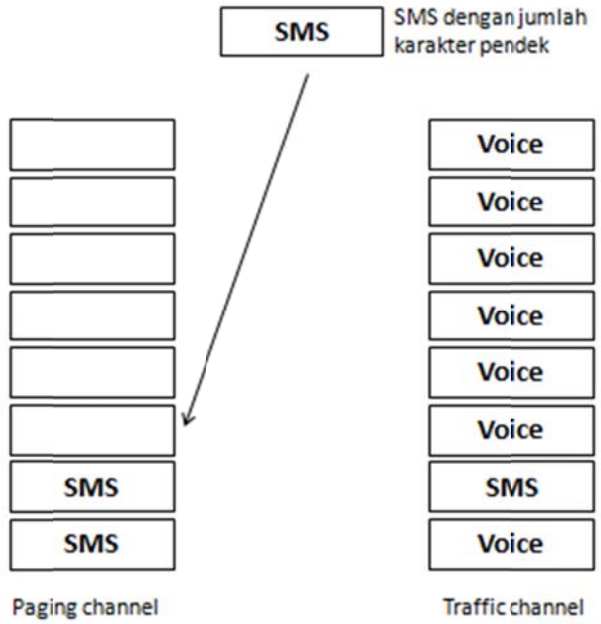
Tipe Terminal	Jumlah Karakter	SMS MO
A	5-160	Traffic channel
	1-4	Access channel
B	5-160	Traffic channel
	1-4	Access channel
C	11-160	Traffic channel
	1-10	Access channel
D	5-160	Traffic channel
	1-4	Access channel
E	5-160	Traffic channel
	1-4	Access channel



Gambar 4: Setting Jumlah Karakter SMS pada Pengiriman SMS MT dengan Mekanisme ADDS Pages untuk Beberapa Tipe BSC.

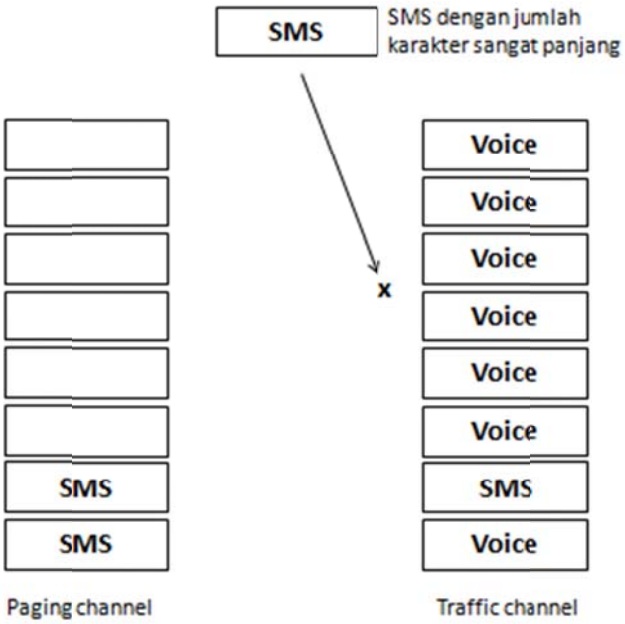
B. Pengiriman SMS MT

Pengiriman SMS MT melalui control channel mempunyai proses pengiriman yang lebih cepat dikarenakan mekanisme pengiriman lebih sederhana. Dari hasil pengamatan, waktu rata-rata dibutuhkan untuk sampai mendapatkan acknowledgement SMS MT sekitar 4 detik. Adapun SMS MT dengan menggunakan traffic channel rata-rata membutuhkan waktu 8-10 detik.



Gambar 5: SMS dengan Jumlah Karakter Pendek Dikirim Melalui Paging Channel.

Hasil pengamatan pengiriman SMS MT pada 3 (tiga) BSC tipe X, Y, dan Z menunjukkan bahwa ketiganya memiliki parameter yang berbeda untuk mengalihkan channel. BSC tipe X akan melewatkan pengiriman paket SMS ke paging channel selama jumlah karakter SMS masih dibawah 79 karakter, tapi BSC tipe Y dan Z melewatkan pengiriman paket SMS ke paging channel ketika jumlah karakter masih 33 dan 10 (Gambar 4). Hal ini menunjukkan bahwa channel traffic pada BSC tipe Z lebih mudah penuh dibandingkan tipe X dan Y ketika layanan voice digunakan secara massal.



Gambar 6: SMS dengan Jumlah Karakter Sangat Panjang Sering Gagal Dikirim Melalui Traffic Channel.

SMS dengan jumlah karakter sangat panjang secara umum langsung dialihakan ke traffic channel dan SMS dengan jumlah karakte pendek akan dikirimkan dengan paging channel (Gambar 5). Ketika dalam kondisi traffic voice yang rendah mekanisme ini tidak akan bermasalah. Namun ketika traffic voice sangat padat sedangkan setting jumlah karakter yang menjadi parameter pengalihan channel tidak diubah maka akan mudah terjadi kegagalan pengiriman karena traffic voice selalu padat sedangkan SMS yang panjang tidak dialihkan ke paging channel (Gambar 6).

Operator CDMA pada dasarnya dapat melakukan pengaturan pengiriman SMS MT ini dengan melakukan perubahan setting panjang karakter yang akan dialihkan ke traffic channel dan paging channel pada BSC. Kemampuan mengubah setting jumlah karakter SMS yang akan dialihkan ke paging channel maupun traffic channel ini akan berguna ketika operator akan mempromosikan layanan voice, terutama pada lokasi yang dilayani BSC tipe Z yang lebih banyak menggunakan traffic channel untuk pengiriman paket SMSnya.

V. KESIMPULAN

Bagi operator CDMA tidak memungkinkan untuk mengatur channel pengiriman SMS MO karena kendali pemilihan sepenuhnya diatur oleh tipe terminal sehingga kepadatan traffic antara MS dan BSC ketika pengiriman SMS MO tidak dapat diatur dengan perubahan setting jumlah karakter SMS. Namun pengaturan channel dapat dilakukan pada sesi pengiriman antara BSC dan MS yaitu ketika mengirim SMS MT. Kemampuan system untuk mengatur channel pengiriman SMS akan memudahkan operator untuk mengantisipasi terjadinya kegagalan pengiriman SMS akibat padatnya jalur traffic channel yang digunakan layanan voice.

Perbaikan mekanisme ini berpotensi meningkatkan performansi layanan SMS sehingga meningkatan utilitas jaringan dengan menekan kegagalan proses pengiriman SMS. Pada akhirnya hasil riset ini akan memberikan dampak positif bagi peningkatan layanan operator CDMA.

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TABEL II: SAMPLE PENGIRIMAN SMS MO DENGAN MEKANISME ADDS TRANSFER

Sno	Interfac	Directio	Signaling	Report Time	IMSI	ESN	CallRefl	Data Le
2	A1	Reverse	EV_S_A1rADDSTransfer	2009-11-10 11:33:07.636	510004112395579	807bd5a6	--	382
7	A1	Forward	EV_S_A1fADDSPage	2009-11-10 11:33:07.808	510004112395579	--	affff	463
252	A1	Reverse	EV_S_A1rADDSPageAck	2009-11-10 11:33:11.406	510004112395579	807bd5a6	--	46

TABEL III: SAMPLE PENGIRIMAN SMS MO DENGAN MEKANISME ADDS DELIVER

Sno	Interfac	Directio	Signaling	Report Time	IMSI	ESN	CallRefl	Data Le
8	A1	Reverse	EV_S_A1prCMServiceRequest	2009-11-10 11:24:50.840	510004112395579	807bd5a6	a10b1	513
9	A1	Forward	EV_S_SccpConnect	2009-11-10 11:24:50.858	510004112395579	807bd5a6	a10b1	7
10	A1	Forward	EV_S_A1pfAssignmentRequest	2009-11-10 11:24:50.858	510004112395579	807bd5a6	a10b1	577
37	A1	Reverse	EV_S_A1prAssignmentComplete	2009-11-10 11:24:51.971	510004112395579	807bd5a6	a10b1	328
44	A1	Reverse	EV_S_A1rADDSDeliver	2009-11-10 11:24:52.055	510004112395579	807bd5a6	a10b1	277
46	A1	Forward	EV_S_A1fADDSDeliver	2009-11-10 11:24:52.213	510004112395579	807bd5a6	a10b1	264
47	A1	Forward	EV_S_A1fClearCommand	2009-11-10 11:24:52.215	510004112395579	807bd5a6	a10b1	12
55	A1	Reverse	EV_S_A1rClearComplete	2009-11-10 11:24:52.708	510004112395579	807bd5a6	a10b1	8

TABEL IV: SAMPLE PENGIRIMAN SMS MT DENGAN MEKANISME ADDS PAGES

Sno	Interfac	Directio	Signaling	Report Time	IMSI	ESN	CallRefl	Data Le
1	A1	Forward	EV_S_A1fADDSPage	2009-11-11 11:37:58.993	510004112395580	--	18fffff	463
52	A1	Reverse	EV_S_A1rADDSPageAck	2009-11-11 11:38:02.458	510004112395580	807bd3e5	--	46
55	A1	Reverse	EV_S_A1rADDSTransfer	2009-11-11 11:38:06.237	510004112395580	807bd3e5	--	382

TABEL V: SAMPLE PENGIRIMAN SMS MT DENGAN MEKANISME ADDS TRANSFER

Sno	Interfac	Directio	Signaling	Report Time	IMSI	ESN	CallRefl	Data Le
1	A1	Forward	EV_S_A1pfPagingRequest	2009-11-10 15:58:31.893	510004112395580	--	18fff	431
10	A1	Reverse	EV_S_A1prPagingResponse	2009-11-10 15:58:34.567	510004112395580	807bd3e5	c049f	505
14	A1	Forward	EV_S_SccpConnect	2009-11-10 15:58:34.586	510004112395580	807bd3e5	c049f	7
15	A1	Forward	EV_S_A1pfAssignmentRequest	2009-11-10 15:58:34.586	510004112395580	807bd3e5	c049f	577
42	A1	Reverse	EV_S_A1prAssignmentComplete	2009-11-10 15:58:35.500	510004112395580	807bd3e5	c049f	328
48	A1	Forward	EV_S_A1fADDSDeiver	2009-11-10 15:58:36.520	510004112395580	807bd3e5	c049f	264
54	A1	Reverse	EV_S_A1rADDSDeliverAck	2009-11-10 15:58:36.781	510004112395580	807bd3e5	c049f	14
55	A1	Reverse	EV_S_A1rADDSDeliver	2009-11-10 15:58:36.781	510004112395580	807bd3e5	c049f	277
56	A1	Forward	EV_S_A1fClearCommand	2009-11-10 15:58:36.788	510004112395580	807bd3e5	c049f	12
63	A1	Reverse	EV_S_A1rClearComplete	2009-11-10 15:58:37.282	510004112395580	807bd3e5	c049f	8
64	A1	Forward	EV_S_SccpDisconnect	2009-11-10 15:58:37.297	510004112395580	807bd3e5	c049f	8

Internetworking Indonesia Journal

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