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Preface

Third International conference on Advanced Computer Science and Information Technology (ICAIT 2014) was held in Sydney, Australia, during July 12~13, 2014. Third International Conference on Digital Image Processing and Vision (ICDIPV 2014), Third International Conference on Information Technology Convergence and Services (ITCSE 2014), Second International Conference of Networks and Communications (NC 2014) were collocated with the ICAIT-2014. The conferences attracted many local and international delegates, presenting a balanced mixture of intellect from the East and from the West.

The goal of this conference series is to bring together researchers and practitioners from academia and industry to focus on understanding computer science and information technology and to establish new collaborations in these areas. Authors are invited to contribute to the conference by submitting articles that illustrate research results, projects, survey work and industrial experiences describing significant advances in all areas of computer science and information technology.

The ICAIT-2014, ICDIPV-2014, ITCSE-2014, NC-2014 Committees rigorously invited submissions for many months from researchers, scientists, engineers, students and practitioners related to the relevant themes and tracks of the workshop. This effort guaranteed submissions from an unparalleled number of internationally recognized top-level researchers. All the submissions underwent a strenuous peer review process which comprised expert reviewers. These reviewers were selected from a talented pool of Technical Committee members and external reviewers on the basis of their expertise. The papers were then reviewed based on their contributions, technical content, originality and clarity. The entire process, which includes the submission, review and acceptance processes, was done electronically. All these efforts undertaken by the Organizing and Technical Committees led to an exciting, rich and a high quality technical conference program, which featured high-impact presentations for all attendees to enjoy, appreciate and expand their expertise in the latest developments in computer network and communications research.

In closing, ICAIT-2014, ICDIPV-2014, ITCSE-2014, NC-2014 brought together researchers, scientists, engineers, students and practitioners to exchange and share their experiences, new ideas and research results in all aspects of the main workshop themes and tracks, and to discuss the practical challenges encountered and the solutions adopted. The book is organized as a collection of papers from the ICAIT-2014, ICDIPV-2014, ITCSE-2014, NC-2014.

We would like to thank the General and Program Chairs, organization staff, the members of the Technical Program Committees and external reviewers for their excellent and tireless work. We sincerely wish that all attendees benefited scientifically from the conference and wish them every success in their research. It is the humble wish of the conference organizers that the professional dialogue among the researchers, scientists, engineers, students and educators continues beyond the event and that the friendships and collaborations forged will linger and prosper for many years to come.

Natarajan Meghanathan
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HARDWARE COMPLEXITY OF MICROPROCESSOR DESIGN ACCORDING TO MOORE'S LAW

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ABSTRACT

The increasing of the number of transistors on a chip, which plays the main role in improvement in the performance and increasing the speed of a microprocessor, causes rapidly increasing of microprocessor design complexity. Based on Moore's Law the number of transistors should be doubled every 24 months. The doubling of transistor count affects increasing of microprocessor design complexity, power dissipation, and cost of design effort.
This article presents a proposal to discuss the matter of scaling hardware complexity of a microprocessor design related to Moore's Law. Based on the discussion a hardware complexity measure is presented.

KEYWORDS

Hardware Complexity, Microprocessor Design, Transistor Count, Die Size, Density.

1. INTRODUCTION

Algorithms' Complexity is regarded as one of the significant measurement, which is appearing along the recent past. Although, there is a rapid development in the algorithmic devices, which involve a computer system as one of their examples; complexity is still occupying a major role in computer design, if it is thought to be oriented towards the hardware or software view [1, 2].
The development of IC technology and design has been characterized by Moore's Law during the past fifty years. Moore's Law states that the transistor count on a chip would double every two years [3, 4]; applying Moore's law in the design of the microprocessors makes it more complicated and more expensive. To fit more transistors on a chip, the size of the chip must be increasing and/or the size of the transistors must be decreasing. As the feature size on the chip goes down, the number of transistors rises and the design complexity also rises.

Microprocessor design has been developed by taking into consideration the following characteristics: performance, speed, design time, design complexity, feature size, die area and others. These characteristics are generally interdependent. Increasing the number of transistors raises the die size, the speed and the performance of a microprocessor; more transistors, more clock cycles. Decreasing the feature size increases the transistor count, the design complexity and the power dissipation [5, 6].

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2. HARDWARE COMPLEXITY MEASUREMENT

Hardware complexity measurement is used to scale the number of elements, which are compounded, along any selected level of hardware processing. Any selected level, includes all the involved structures of hardware appearing beyond a specific apparatus. The hardware complexity measurement id defined as:

$$A = | E | \qquad (1)$$

where, E is the multitude of the elements emerging in a hierarchal structural diagram.

In order to illustrate when a processor level is selected (see Figure.1), the apparatus complexity measure (ACM) would be defined by the amount of the beyond registers, ALU and the Control Unit.

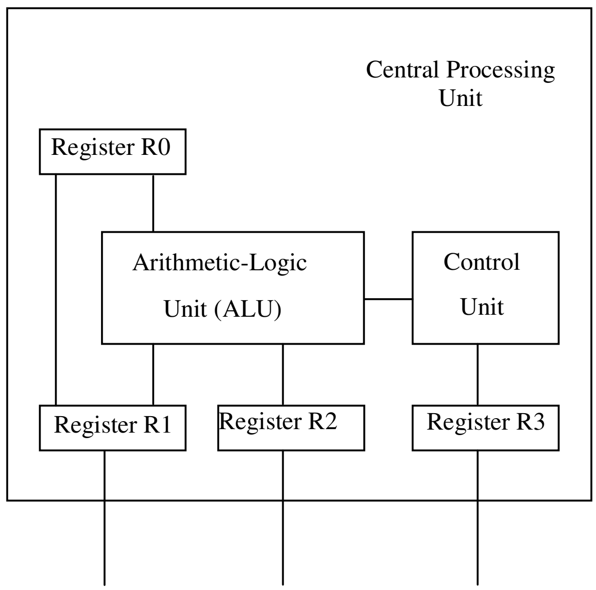

Figure.1.View of a CPU complexity Level, [7].

For the given example of Figure.1: ACM = $| E |$ = 6.
So, the increasing of the number of elements at any processor level increases the hardware complexity of that level.

3. PHYSICAL LIMITATION OF INCREASING THE NUMBER OF TRANSISTORS

Increasing the number of transistors will be limited due to several limitations, such as increasing the density, the die size, decreasing the feature size, the voltage [8, 9, 10].

Since the surface area of a transistor determines the transistor count per square millimeter of silicon, the transistors density increases quadratically with a linear decrease in feature size [11]. The increase in transistor performance is more complicated. As the feature sizes shrink, devices shrink quadratically in the horizontal and vertical dimensions. A reduction in operating voltage to maintain correct operation and reliability of the transistor is required in the vertical dimension shrink. This combination of scaling factors leads to a complex interrelationship between the transistor performance and the process feature size.

Due to the shrinking of the pixel size and the increasing of the density, the hardware complexity raises. If the pixel size shrinks double and the density increases double every two years according to Moore's Law, the physical limitation will definitely appear in few years, which means that it will be very difficult to apply Moore's Law in the future. Some studies have shown that physical limitations could be reached by 2018 [12] or 2020-2022[13, 14, 15, 16].

Applying Moore's Law by doubling the number of transistors every two years increases the speed and performance of the processor and causes increasing the processor's hardware complexity (see Table 1), which will be limited after a few years [17, 18, 19, 20].

Table 1. Complexity Of microchip And Moore's Law

Year	**Microchip Complexly Transistors**	**Moore's Law: Complexity: Transistors**
1959	1	$2^0 = 1$
1964	32	$2^5 = 32$
1965	64	$2^6 = 64$
1975	64,000	$2^{16} = 64,000$

Table 2 shows the apparatus complexity measurement of different microprocessors from 1971 till 2012.

Table 2. Evolution of Microprocessors And Apparatus Complexity Measurement: 1971 to 2012

Manufacturer	**Processor**	**Date of introduction**	**Number of transistors (Apparatus Complexity)**	**Area [mm^2]**
Intel	Intel4004	1971	2,300	12
	Intel8008	1972	3,500	14
	Intel8080	1974	4,400	20
	Intel8085	1976	6,500	20
	Intel8086	1978	29,000	33
	Intel80286	1982	134,000	44
	Intel80386	1985	275,000	104
	Intel80486	1989	1,180,235	173
	Pentium	1993	3,100,000	294
	Pentium Pro	1995	5,500,000	307
	Pentium II	1997	7,500,000	195
	Pentium III	1999	9,500,000	128
	Pentium 4	2000	42,000,000	217
	Itanium 2 McKinely	2002	220,000,000	421

	Core 2 Duo	2006	291,000,000	143
	Core i7 (Quad)	2008	731,000,000	263
	Six-Core Core i7	2010	1,170,000,000	240
	Six-Core Core i7/8-Core Xeon E5	2011	2,270,000,000	434
	8-Core Itanium Poulson	2012	3,100,000,000	544
MIPS	R2000	1986	110,000	80
	R3000	1988	150,000	56
	R4000	1991	1,200,000	213
	R10000	1994	2,600,000	299
	R10000	1996	6,800,000	299
	R12000	1998	7,1500,000	229
IBM	POWER3	1998	15,000,000	270
	POWER4	2001	174,000,000	412
	POWER4+	2002	184,000,000	267
	POWER5	2004	276,000,000	389
	POWER5+	2005	276,000,000	243
	POWER6+	2009	790,000,000	341
	POWER7	2010	1,200,000,000	567
	POWER7+	2012	2,100,000,000	567

4. INCREASING THE DIE SIZE

This article suggests, as a solution for avoiding the physical limitations mentioned above, a new approach of constructing a chip with die size that contains free spaces for allowing to apply the Moore's Law for a few years by doubling the number of transistors on a chip without touching the voltage, the feature size and the density, in this case only the hardware complexity will be raised.

Let us assume a microprocessor (let's say X) has the following specifications: date of introduction – 2015, one-layer crystal square of transistors, transistor count (number of transistors) – 3 billion, pixel size (feature size) – 0.038 micron, die size (area) – 2400 mm2: for transistors – 600 mm2 and free space – 1800 mm2 (see Figure. 2).

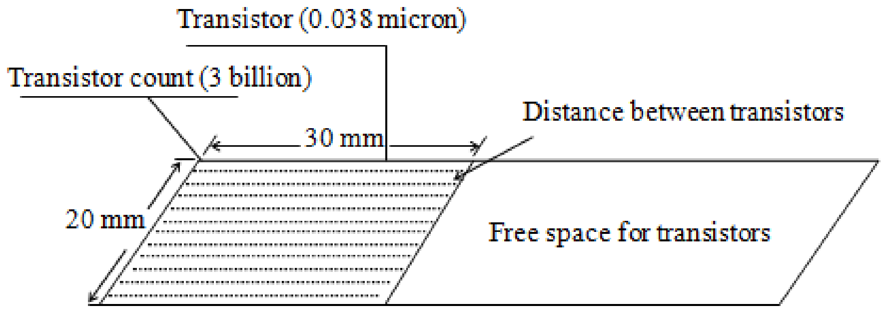

Figure 2. Crystal Square of Transistors

In this case the number of transistors will be doubled after two year (2017) without touching the feature size, die size, voltage and density. In 2017 year a new microprocessor (let's say X1) will have the following specifications: date of introduction – 2017, one-layer crystal square of transistors, transistor count (number of transistors) – 6 billion, pixel size (feature size) – 0.038 micron, die size (area) – 2400 mm^2: for transistors – 1200 mm^2 and free space – 1200 mm^2 and so on. When the number of transistors would occupied all the free space, the architects can decrease the feature size and increase the density without touching the die size (see Table 3).

Table 3. Assuming Evolution Of Microprocessors: 2015 to 2021

Microprocessor	**Date of introduction**	**Number of transistors (billion)**	**Feature size (nm)**	**Area [mm^2]**	
				For Transistors	**Free space**
X	2015	3	38	2400	
				600	1800
X1	2017	6	38	1200	
				1200	1200
X2	2019	12	38	2400	
				2400	
X3	2021	24	28	2400	

As shown in the table above, several measures of microprocessors technology, such as hardware complexity can be changed (increased) during few years, while the others can be fixed.

5. CONCLUSION

The problem of applying Moore's law in microprocessor technology as much as possible is still topical research field although it has been studied by the research community for many decades. The main objective of this article is to find a suitable solution for avoiding physical limitation in manufacturing of microprocessors technology and applying Moore's Law for a long time.

As mentioned above, the physical limitations could be reached by 2018 or 2022. Applying the new approach in microprocessor technology will delay the physical limitation for few more years, because it doubles the transistor count every two years based on Moore's Law, with increasing the die size and the hardware complexity, without decreasing of the feature size and increasing of the density.

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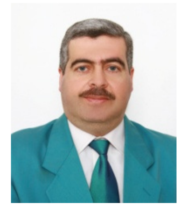

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USING GRID PUZZLE TO SOLVE CONSTRAINT-BASED SCHEDULING PROBLEM

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ABSTRACT

Constraint programming (CP) is one of the most effective techniques for solving practical operational problems. The outstanding feature of the method is a set of constraints affecting a solution of a problem can be imposed without a need to explicitly defining a linear relation among variables, i.e. an equation. Nevertheless, the challenge of paramount importance in using this technique is how to present the operational problem in a solvable Constraint Satisfaction Problem (CSP) model. The problem modelling is problem independent and could be an exhaustive task at the beginning stage of problem solving, particularly when the problem is a real-world practical problem. This paper investigates the application of a simple grid puzzle game when a player attempts to solve a practical scheduling problem. The examination scheduling is presented as an operational game. The game's rules are set up based on the operational practice. CP is then applied to solve the defined puzzle and the results show the success of the proposed method. The benefit of using a grid puzzle as the model is that the method can amplify the simplicity of CP in solving practical problems.

KEYWORDS

Constraint Programming; Constraint Satisfaction Problem; Examination scheduling; Grid puzzle

1. INTRODUCTION

Constraint Programming (CP) is a programming paradigm used for modelling and solving problems with a discrete set of solutions [1]. The idea of the CP is to solve problems by stating a set of constraints (i.e. conditions, properties or requirements) of the problems and finding a solution satisfying all the constraints using a constraint solver [2, 3]. The main advantage of the CP approach is the declarative ability of the constraints which makes it suitable for solving complicated real-life problems. In order to solve the problem using CP, a model is required and it is typical to define the problem as Constraint Satisfaction Problem (CSP). CSP is defined by a sequence of variables. A finite sequence of variables Y := y1, . . ., yk where k > 0, with respective domains D1, . . .,Dk . A finite set C of constraints are used to limit the domain for each variable [4].There is another problem called Constraint Satisfaction Optimisation Problem (CSOP) which can be seen as an 'upgrade' of CSP in the sense that solutions are not only feasible but also achieve optimality of an integrated cost function [5]. Formalism of CSP is defined in [6]. Typically, to solve practical operational problems using CP, ones are only required to model the

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problems and using CP solvers to solve the problems. There are several available CP solvers for both CSP and CSOP including: Choco, Ilog, ECLiPSe®, Gecode, Comet, CHIP, and Jsolve. Problem modelling is one of the key steps of using CP to solve problems successfully. This paper will focus on a grid puzzle-game as inspiration to model and solve the problem. The rest of the paper is organised as follows; Section 2 discusses the current CP applications, Section 3 provides a background of typical grid puzzle game, Section 4 demonstrates the using of grid puzzle to model a scheduling problem, Section 5 discusses the CP implementation, Section 6 discussed the result of the paper and, Section 7 is the conclusion.

2. CP APPLICATIONS

CP has been applied to solve several applications successfully. In healthcare, CP is used to assign shifts to medical staffs. Several rules can be imposed to solve the problem and create the realistic schedule including; assignments meet the demand for every shift, staff availability status, and the fairness of the generated schedule for every assigned staff [7]. Further requirements to schedule working time for medical residents are addressed in [8]. The requirements that make this scheduling different from the typical medical staff come from the fact that a resident is not only the medical staff, he or she is also a student in training i.e. the schedule have to provide a good balance between education and medical service activities. CP is also used for scheduling facilities in healthcare such as an operation theatre[9]. At airports, [10] investigates the use of CP to schedule aircraft departure to avoid traffic congestion, while [11] focuses the study on generating a contingency plan to handle unexpected failures affecting a regular traffic schedules. At academic institutes, manual timetabling can be a very time-consuming task, [12] presents CP based school timetabling to minimise idle hours between the daily teaching responsibilities of all teachers. [13] develops an examination timetabling to tackle important constrains such as schedule clashing, room capacity, and avoiding an allocation of two difficult subjects in consecutive time slot.

3. GRID PUZZLES

Grid Puzzles are board games contained within an NxM lattice where players are usually required to locate symbols or number to meet the objective of the game. There have been several studies using CP to solve grid puzzle games. Akari, Kakuro, Nurikabe have been studied [14]. Akuro is a game that provides clues for a number of tokens, which the game called ‘lights’, for certain grid, players are asked to locate tokens such that all conditions are satisfied. Kakuro requires players to fill a numbers to grids to generate sums to meet vertical and horizontal clues. Another classical puzzle game problem that is usually mentioned in CP literature is the N-queen problem. In this problem, one is asked to place N queens on the $N\times N$ chess board, where $N \geq 3$, so that they do not attack each other. Better known puzzle games are Crosswords and Sudoku, and MineSweeper. Crosswords are games in which one is required to fill pre-defined vocabulary into the NxN grids in a way that none of the words are used more than once. Sudoku is usually played on 9 x 9 grids with some grids having pre-defined values. The game‘s rule involves giving a value assignment so that all rows and column as well as sub-regions 3 x3 grid are pairwise different. Finally, Minesweeper is one of the most popular ‘time-killer’ computer games which has the objective to determine the ‘mine’ on a grid where the game might provide hints for a number of mines in the grids. The example of the Grid puzzle games are shown as Figure 1.

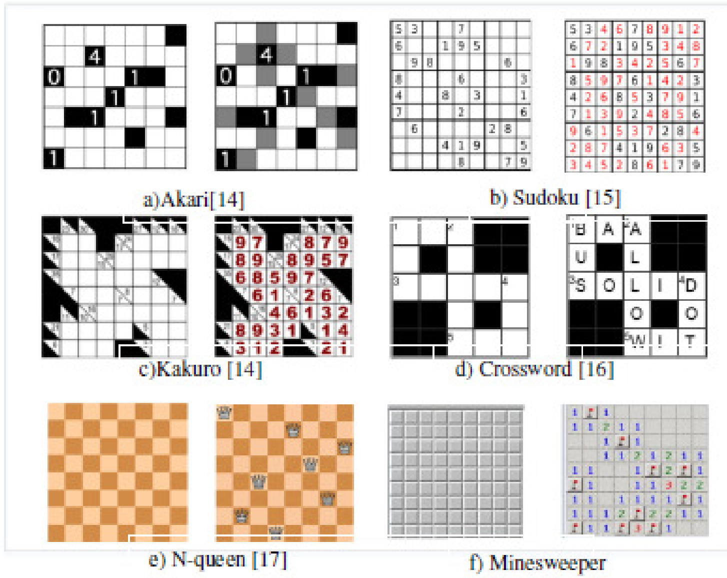

Figure 1. Typical grid puzzle games and their solutions [14-17]

4. CP APPLICATIONS

The mechanism of tackling CSP using CP typically relies on the domain reduction process. To solve a problem, a set of constraints related to the problem needs to be identified and later on applied to a problem. Some of the constraints are associated with each other to formulate a constraint network. Each constraint applied to the model is usually associated with finite domain variables. Solving the problem is a process of reducing the domain of each variable until there are no conflicted domains remaining. So, constraint programmers will need to understand the variables, domain and constrains of the problem. Particularly they need to have a comprehensive understanding of the relationship among associated constraints and variables. This can be exhaustive task when solving complicated practical problems. Figure 2 visualises an abstraction of a constraint network and variable network of CP as describe above.

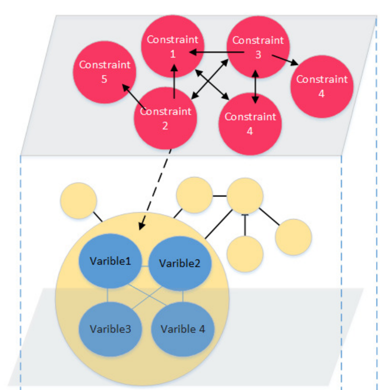

Figure 2. CP problem solving

Grid puzzles representations, i.e. using 2 Dimension (2D), NxM , lattice to represent finite values/states of variables,which can be applied to model many practical problems. With that, the relationship between variables can be visualised. Rules of the games can be set up to reflect businesses rules, and typical constraints can be applied to the model just as what shown in solving general puzzle games. This paper demonstrates the use of grid puzzles for solving an examination scheduling problem which is outlined as follows:

Problem definition: The problem is an examination scheduling problem. It is mainly concerned with assignment of subjects for exam into given time slot during examination period. The generated result shall be able to indicate the day of the week the exam is allocated together with the room assigned. The assumption of this problem is that this schedule is for a package registration system in which student in the same year will study the same subjects. The problem is concerned with practical constraints such as certain subjects requiring larger room and every student cannot take exams in more than 2 subjects in a day. Solving this problem manually, i.e. using human decision making, is highly time-consuming and prone to mistakes such as schedule conflicted issues. This research will apply the grid puzzle, shown in Figure 3, to tackle the described problem.

0

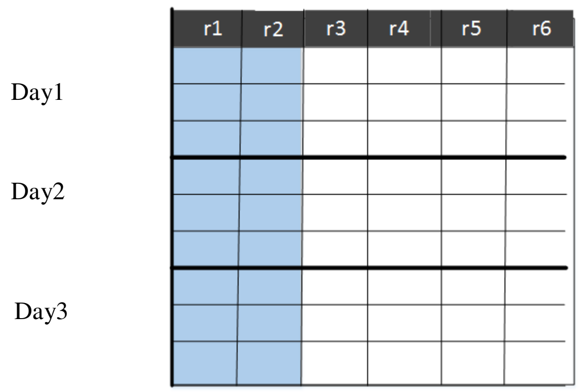

Figure 3. Grid puzzle for examination scheduling problem

From Figure 3, it can be seen that the columns represent rooms or venue of the exam. There are 2 types of rooms in this problem: 1) regular-sized rooms indicated by the white-grids and 2) larger sized rooms indicated by the shaded-grids. Rows of the puzzle represent time slots of the exam. Assuming there are 3 timeslots per day, the thick horizontal lines are used to separate days during the exam period. Thus, Figure 3 is shown that there are 6 rooms available for the exam with 2 large rooms and the exam period lasts 3 days. The objective of the defining game is to assign subject ID to the puzzle such that operational constraints are satisfied. The rules of the game are setup to match the businesses rules of the problem as detailed in Table 1.

Table 1 Business's and game's rules of the problem

Business 's rules	**Game 's rules**
A. All subjects have to be assigned to the schedule and each subject takes only 1 exam	A. All the numbers indicating subject IDs, can be used only once
B. Students should not take more than 2 exams in a same day	B. In a day sub-region, the number of assigned subjects for each year cannot be over 2
C. Some subjects require large rooms	C The subjects that requires large rooms should be assigned to the given area only

5. IMPLEMENTATION

The problems is implemented by using Choco, a Java based CP library. The constraints declared in Section 4 as the rules of this game can be solved by CP as follows:

5.1 “All the numbers indicating subject IDs, can be used only once”

Global constraint is a category of constraints that are defined for solving practical problems where association between variables are not limited to ‘local’ consideration [18]. Global constraints are well documented to define 423 constraints in [19]. Global cardinality is a global constraints used to tackle this requirement. The constraint enable limiting the lower bound and upper bound together with the number of times that those values can be used. Imposing the Global cardinality constraint to satisfy this rule in Choco is as the following simplified statement.

Impose globalCardinality(S,[0,20],all the number in the range except 0 is only assigned 1 time)

The representation for this constraint is depicted in Figure 4. In this application, each variable Subject ID (S) = {1, 2, 3, 4…20) represents a sequence of continuous subject ID. A dummy value 0 is required to indicate that there is no assignment given to that timeslot. Therefore, the domain of this variable, i.e. for 20 subjects, is ranged from [0, 20). The global cardinality is enforced every S, except 0, appearing only once

r1	r2	r3	r4	r5	r6
S1	S2	S3	S4	S5	S6
					Sn

Figure 4. Problem modelling to tackle constraint 5.1

5.2 “In a day sub-region, the number of assigned subjects for each year cannot be over 2”

The model of the year of subject is similar the Subject ID as shown in Figure 5. There are four year of students from 1 to 4. However, similar to the previous constraint, a dummy value (0) is required to indicate a ‘no-assignment’. The domain for this variable is therefore ranged from [0, 4].

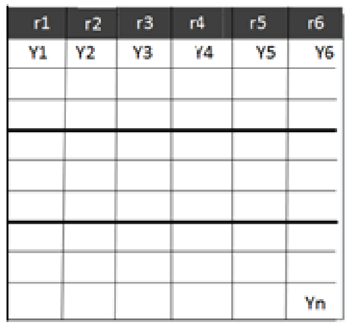

Figure 5. Problem modelling to tackle constraint 5.2

Due to the fact that rows in the puzzle indicate time slot of the exam, Globalcardinality is used to control the number of the domain 1-4 appearing at most twice in each day region. The algorithm for tackling this rules of the defined puzzle is shown in Figure 6.

```
FOR Each day
  Impose GlobalCardinality(Year, [0,4],all the number in the range except 0 is only
  assigned 2 time)
ENDFOR
```

Figure 6. Algorithm for tackling the constraint 5.2

5.3 "The subjects that requires large-rooms should be assigned to the defined areas only"

Two larger rooms are defined for the first two columns as shown in Figure 7. Assignment to this area are limited to the subject that required. The subject that require larger room have to be defined in a problem statement, and this value will never be assigned outside that area.

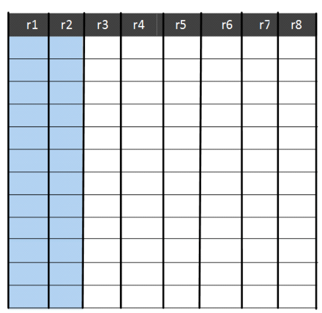

Figure 7 Problem modelling to tackle constraint 5.3

To implement this constraint in Choco, the constraint 'among' is applied to limit a subject ID assignment bounded in a predefined list of large rooms. This constraint is only applied to the shaded area of the puzzle. So a constraint is defined within a nested loop. The algorithm is depicted as Figure 7a.

```
FOR  i = 0 To LastRow
        For   j =  To LastColumnLargeRoom
        Impose among (S[i][j], LargeroomList)
        ENDFOR
ENDFOR
```

Figure 7a. Problem modelling to tackle constraint 5.3

5.4" Associating IDs to other attributes"

Being that a grid puzzle is 2D, the limitation in problem modelling is an unknown variable that can be solved one at a time. In practice, there are multiple variables to consider in one problem. For example, the example problem involved with Subject ID and year of the subject. Modelling the problem using a grid puzzle requires to solve the problem separately. The internal constraint beside the explicit constraints of the problem is required to associate with other solving variables. This can be done by imposing constraints to associate variables. In CP, a compatibility between variable can be enforced by declaring a feasible pair i.e. between subject ID and the year variable. This will enable interpretation of which subject is belong to. The algorithm for binding 2 variables is indicated as Figure 8.

```
FOR  i = 0 To LastRow
        For   j =  To LastColumnLargeRoom
        Impose feasiblepair (S[i][j],Yr[i][j],DefinedPair)
        ENDFOR
ENDFOR
```

Figure 8. Algorithm for associating Subject ID with its year

6. RESULTS AND DISCUSSION

This Section demonstrates the use of the grid puzzle defined to solve the exam scheduling problem. The sample question is given in Table 2, and brief clarification on the problem is as follows:

Table 2. Requirements of the problem

Subject ID	Year	Large section (yes or no)
1	1	Yes
2	1	No
3	1	No
4	1	No
5	1	No
6	2	No
7	2	Yes
8	2	No
9	2	No
10	2	No
11	3	No
12	3	Yes
13	3	No
14	3	No
15	3	No
16	4	No
17	4	No
18	4	No
19	4	Yes
20	4	No

From Table 2., there are 5 subjects for each year i.e. subject 1-5 for the first year, 6-10 for the second year, 11-15 for the third year, and 16-20 for the fourth year. 5 subjects require larger room: 1, 3, 7, 12, and, 19. Solving this grid puzzle using our proposed method can result in the following scheduling as depicted in Figure 7.

r1	r2	r3	r4	r5	r6
19	12	20	15	10	9
3	1	0	0	0	0
0	0	0	0	0	0
7	0	18	17	14	13
0	0	8	5	4	0
0	0	0	0	0	0
0	0	16	11	6	2
0	0	0	0	0	0
0	0	0	0	0	0

Figure 7. Scheduling result

The result indicates that 3 defined major constrains are satisfied; 1) all subjects are allocated to the schedule 2) there are no more than 2 exams for every year subject and 3) the subject that has larger class-sizes are allocated to the larger room.

In this paper schedule result is generated under CSP focus. Figure 7 show only one possible solution, actually several more possible solutions can be generated. CSP solving does not specify which solution is better than the other, when an optimal solution is required, the problem can be simply expanded to the “Constraint Satisfaction Optimisation Problem (CSOP)” by applying objective function to the model e.g. minimise spanning time.

7. CONCLUSION

This paper aims at tackling the problem formulation issue of using CP solving CSP. Applying grid puzzles to represent the problem is an alternative solution to get started solving practical problem. The paper shows the success of using the grid puzzle to solve simple examination scheduling problem. Three operational constraints are addressed; 1) all the subjects are scheduled the exam 2) students can take at most 2 subjects per a days and 3) the schedule allocates the rooms to meet capacity requirement. The future work of this research is to impose more constraint to this problem also applying the model to similar scheduling problems. This work has led to the new research question is the proposed method simple enough for non-computing user? The planned field evaluation is to conduct to evaluation of the proposed method by university administration staff. Subject to success of the proposed method, anyone not limited to computing users who understand the problem can contribute in the problem solving process using CP. In practice, operational workers might be able to formulate a CSP model to cooperate with a Constraint Programmer to shorten problem solving time, or they can even solve the problem by themselves.

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A THEORETICAL FRAMEWORK OF THE INFLUENCE OF MOBILITY IN CONTINUED USAGE INTENTION OF SMART MOBILE DEVICE

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ABSTRACT

In the face of fierce competition in the mobile device market, the only way for smart mobile device producers to maintain and expand their market share is to design and develop products that meet users' expectations. With the increasing importance of smart mobile devices in people's lives, mobility is likely to be a key feature that addresses the needs of mobile phone users. Therefore, this survey investigates mobility in four essential aspects: spatiality, temporality, contextuality, and social fluidity with the purpose of finding mobile device functions that users value highly. Special attention is paid to how these constructs affect continued usage intention (CUI) through two intermediates: user confirmation and user satisfaction.

KEYWORDS

Mobility, continued usage

1. INTRODUCTION

With the current boom in information and communication technology (ICT), mobile devices are an indispensable part of people's working and social lives. Mobile devices attend to users' daily routines and assist them in handling contextual tasks and staying current with their social needs. Kakihara and Sorensen (2004) noted that ubiquitous and pervasive mobile technologies manifested themselves at the turn of the millennium. Since then, mobile communication has proven to be desirable to all types of users (Haney, 2005).

Mobility is a key requirement for addressing the needs of mobile phone users. That is to say, users tend to adopt to devices that facilitate mobility as integral parts of their lives. Thus, it would be worthwhile to advance our understanding of how mobility affects continued usage intention of smart phones, which are enabled with either 3G or 4G technology.

Mobility traditionally refers to the movement of objects from one location to another, as well as their transformation in terms of state, condition, or structure (Kakihara and Sorensen, 2004). Mobility creates choices and new freedoms for users (Keen and Mackintosh, 2001) and allows users to deal with the environment dynamically. Mobility is a central and primary factor affecting

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continued usage intention of mobile devices (Lee, Kang, & Kim, 2007). Based on the expectation confirmation theory, once a user experiences using a mobile device and his or her expectations are confirmed, he or she will continue using the device. In this study, we investigate mobility in four essential aspects: spatiality, temporality, contextuality, and social fluidity. We also investigate how these four dimensions affect the CUI of mobile devices.

2. THEORETICAL FRAMEWORK

Continued usage of technology is defined as the long-term usage of an innovation or information technology (Bhattacherjee, 2001; Premkumar and Bhattacherjee, 2008). Conceptually, this continuous usage would occur on a regular or ad hoc basis (Meister & Compeau, 2002). For example, users who habitually book hotels through online reservation web sites, but do not visit these sites regularly, are still considered continuous users. This phenomenon can be regarded as the post-acceptance stage in the innovation diffusion model, wherein users accept a technology, continue using it, and possibly even consider this usage as normal activity (Rogers, 1995; Cooper and Zmud, 1990).

The concept of continued usage has been examined in such contexts as implementation (Zmud, 1983), system survival (Cooper, 1991), incorporation (Kwon & Zmud, 1987), routinization (Cooper and Zmud, 1990), and infusion (Meister & Compeau, 2002; Bell, 2004) in the information technology (IT) and information systems (IS) implementation literature. These studies acknowledge the existence of a post-acceptance stage where using an IS technology or service transcends conscious behavior and becomes part of the user's routine activity.

The main stream of research on the continued usage of technology relies on the cognitive dissonance theory, which states that if a person's attitude and behavior are at odds (in a state of dissonance), then that person may change his or her attitude to reduce dissonance (Festinger, 1957). This theory is concerned with the degree to which relevant cognitive elements, such as knowledge, attitudes, and beliefs about the self and the environment, are compatible. In time, the cognitive dissonance theory evolved into the expectation-disconfirmation-satisfaction paradigm, which in turn gave rise to the expectation disconfirmation theory (EDT) (Oliver, 1980; Bhattacherjee, 2001). EDT was specifically designed to explain post-adoption behavior following one's first-hand experience with the target system. It is a process model that utilizes users' backward-looking perspectives or retrospective perceptions to explain their intentions and behaviors based on their initial expectations and their actual usage experience, which includes confirmation and satisfaction. Confirmation refers to a customer's evaluation or judgment of the performance of a service or technology as compared to a pre-purchase comparison standard. Moreover, user satisfaction is a pleasurable, positive emotional state resulting from a specific experience (Locke, 1976; Wixom and Todd, 2005). In this context, satisfaction is an affective state representing an emotional reaction to the usage of a technology (Oliver, 1992; Spreng et al., 1996).

EDT predicts that, in theory, continued usage intention depends on the degree of satisfaction and confirmation (Bhattacherjee, 2001; Lin et al., 2005). First, users form initial expectations of a specific service or technology prior to adoption, after which they compare their perceptions of its performance with their prior expectations and determine the extent to which their expectations were confirmed. They thus form a feeling of satisfaction or dissatisfaction based on the degree of their confirmation or disconfirmation. Finally, satisfied users form intentions to reuse the service or technology in the future (Anderson et al., 1994; Bearden et al., 1983; Churchill et al., 1982; Fornell et al., 1984; Oliver, 1980; Oliver et al., 1981; Yi, 1990).

Thus, EDT suggests that users' continuance intention is determined by satisfaction. Igbaria, and Tan (1997) similarly found that satisfaction is a major determinant of continued usage. Bokhari (2005) performed a meta-analysis and empirically validated a positive relationship between satisfaction and system usage. Satisfaction may thus be a determining factor in the user's intention to continue using a technology, due to the positive reinforcement of his or her attitude toward the technology. Therefore, we propose the following hypotheses:

H1. Confirmation has a positive influence on user satisfaction.
H2. Confirmation has a positive influence on CUI.
H3. User satisfaction has a positive influence on CUI.

As suggested by Ling & Yttri (2002), user satisfaction with a smart mobile device is influenced by the device's quality, which in turn, depends on its response time, ease of use (Swanson, 1974), accuracy, reliability, completeness, and flexibility (Hamilton and Chervany, 1981). Seddon (1997) employed the IS Success Model (DeLone and McLean, 1992) and found that system quality is positively related to satisfaction (Dourish, 2001). The IS Literature (VanDyke et al., 1997) shows that system quality promotes user satisfaction in the marketing field (Collier and Bienstock, 2006). Thus, we have the following hypotheses:

H4. The system quality of a smart mobile device has a positive influence on the satisfaction of its user.
H5. The system quality of a smart mobile device has a positive influence on its user's CUI.

Kakihara and Sorensen (2002), Green (2002), Sorensen and Taitoon (2008), Boase and Kobayashi (2008), Chatterjee et al., (2009), and LaRue et al., (2010) investigated mobility along four dimensions: spatial, temporal, contextual, and social fluidity. the current study investigates the perceived performance of smart mobile devices in terms of these four dimensions and how their performance affects users' confirmation and satisfaction of using a mobile device.
Spatial mobility denotes physical movement, which is the most immediate aspect of mobility (Ling and Yttri, 2002). Spatial mobility refers not only to the extensive geographical movement of people, but also signifies the global flux of objects, symbols, and space itself, and as such evokes complex patterns of human interaction (Kakihara and Sørensen 2002). The rapid diffusion of ICT in general and mobile communication technologies—particularly smart mobile phones—has further energized human geographical movement, or nomadicity, in urban life, work environments, and many other societal milieus (Dahlbom, 2000; Chatterjee et al., 2009). Furthermore, devices that combine a GPS sensor, Internet access via a 3G or 4G network, and a digital camera enable users to integrate spatiality into their daily lives (Egenhofer, 1998). Location-aware applications, such as google maps, help users position where they are and identify nearby resources e.g. banks and restaurants. Thus, smart mobile devices are more likely to be used in situations where users experience a high degree of spatial mobility, and are likely to increase the satisfaction of these users. Therefore, we hypothesize that:

H6a: Spatial mobility has a positive influence on confirmation after usage of a smart mobile device.
H7a: Spatial mobility has a positive influence on user satisfaction after usage of a smart mobile device.

Temporal mobility denotes the flexibility of task scheduling and coordination under different situations (Ling and Yttri, 2002). Some studies (for example, Barley, 1988) suggest that changes in work orders are enabled by information and communication technologies. Barley (1988) characterizes temporal mobility using the dichotomy of monochronicity and polychronicity. Monochronicity refers to situations in which people seek to structure their activities and plan for events by allocating specific slots of time to each event's occurrence, whereas polychronicity refers to situations in which people place less value on the divergence of structural and interpretive attributes of the temporal order.

Short message system (SMS), google calendar and other mobile applications on scheduling, using push technology found in most smart mobile devices, remind users of the latest appointments on their online calendars, allowing them to deal with multiple tasks simultaneously. ICTs allow information and ideas to be instantaneously transmitted and simultaneously accessed across the globe (Urry, 2000). Thus, it can be argued that such "instantaneity" of time in contemporary society and cyberspace further increases the polychronicity of human activities, which can no longer be restricted by a linear "clock-time" perspective. Human interactions are now highly mobilized into multiple temporal modes depending on users' perspectives and their interpretation of time. This situation leads to a complex social environment where the polychronicity of interaction among humans is intertwined (Kakihara and Sørensen, 2002) and performing multiple tasks simultaneously becomes possible (Datamonitor, 2000; May, 2001).

Temporal mobility implies that people can deliver or receive time-sensitive information at their mobile devices (Tsalgatidou and Pitoura, 2001). Time-critical situations where immediacy is essential, or at least desirable, typically arise from external events. Hence, the always-on connectivity of smart mobile devices is important for resolving these situations. On-demand push-technological solutions (alerts and reminders) allow users to handle time-critical events. Thus, we hypothesize that:

H6b: Temporal mobility has a positive influence on confirmation after usage of a smart mobile device.
H7b: Temporal mobility has a positive influence on user satisfaction after usage of a smart mobile device.

People's behaviors are inherently situated in a particular context that frames, and is recursively reframed by, their interactions with the environment (Kakihara and Sørensen, 2002). Contextual mobility, which refers to the ability to capture information of a situation dynamically and react accordingly, is critical for humans responding to different interactional aspects such as "in what way," "in what particular circumstance," and "toward which actor(s)". Context-aware applications, such as weather apps, inform users of current temperature and weather conditions in the district where he or she is situated. This contextual feature of mobile devices is highly valuable and tremendously increases usability (Baldauf, 2007).

Mobile devices such as Blackberrys are developed to increase users' productivity by providing contextual information (Peters, 2002). People constantly look for more efficient and dynamic ways of carrying out business activities (Kalakota and Robinson, 2001). The chief benefit of portable computing devices lies in increasing workers' productivity, as businesspeople who can check their schedules and access corporate information as needed are more efficient than their competitors who have to call their offices continually (Delichte, 2001; Maginnis et al., 2000). The contextuality of smart mobile devices helps improve users' efficiency, and therefore enhances their confirmation of, and satisfaction with, their mobile phones. In sum of the above arguments, we have the following hypotheses:

H6c: Contextual mobility has a positive influence on confirmation after usage of a smart mobile device.
H7c: Contextual mobility has a positive influence on user satisfaction after usage of a smart mobile device.

Social mobility signifies the dynamic interaction among users (Dourish, 2001). Nowadays, most smart mobile devices like the iPhone 5 or the Samsung Galaxy Note II have incorporated common means of communication, such as email, Skype, instant messaging, Facebook, Twitter, and SMS to facilitate connectivity among users. Due to their portability and "person-to-person" connectivity capability, mobile phones have facilitated a cultural shift from maintaining strong ties to maintaining weak ones. The mobility of mobile phones frees people from physical confines (Adam, 1995; Cairncross, 1997). It also facilitates interactions with diverse social ties, accelerating the rise of networked individualism (Haythornthwaite and Wellman, 2002; Wellman, 2001; Wellman, 2002). A study by Kopomaa (2000) shows that mobile phones affect urban society because family members coordinate their lives using mobile phones (Ling, 1999a, b; Ling and Yttri, 2002). Based on these benefits, we hypothesize that:

H6d: Social mobility has a positive influence on confirmation after usage of a smart mobile device.
H7d: Social mobility has a positive influence on user satisfaction after usage of a smart mobile device.

2.1 Control Variables

The backgrounds of users may influence CUI (Chiasson and Lovato, 2001). Prior experience, for example, may be proportionate to confirmation (Rosson, Carroll and Rodi, 2004). The education of users sometimes increases with their understanding of mobile devices. Different levels of understanding result in different presumptions, influencing user confirmation. Therefore, it was necessary to control the possible effects of gender, age, prior experience, and education on CUI.

2.2. Data Collection

Given the research objectives, we adopted a survey approach as the research method. We developed a survey instrument to collect quantitative data for model and hypothesis testing. Recommendations from five IS experts and two management information system (MIS) professors were incorporated to improve the instrument. A pilot study was conducted to further evaluate the instrument. The population of this survey included individuals with experience in using pocket PC mobile phones. Appendix A lists the measurement items. The questionnaire consisted of 26 items to assess the seven constructs of our proposed theoretical model: spatial mobility (Spt), temporal mobility (Tmp), contextual mobility (Cnt), social fluid mobility (SFl), system quality (SQ), user satisfaction (USat), confirmation (Conf), and CUI. The first four constructs—Spt, Tmp, Cnt, and SFl, consisting of 14 items—were mainly operationalized from studies by Kakihara and Sørensen (2002) and Chatterjee et al., (2009). USat was measured using four items adopted from studies by Oliver (1980) and Spreng and Chiou (2002). CUI, which consisted of four items, was measured by using the scale recommended by Agarwal and Prasad (1997). All the constructs were measured on a seven-point Likert scale, ranging from (1) "strongly agree" to (7) "strongly disagree." Some demographic data regarding age, gender, and level of education were collected at the end of the questionnaire.

3. CONCLUSIONS

There are various limitations in this study. This study viewed continued usage as an extension of acceptance behaviors (that is, they employed the same set of pre-acceptance variables to explain both acceptance and continued usage), and implicitly assumed that continued usage goes together with technology acceptance (for example, Davis et al., 1989; Karahanna et al., 1999). We were therefore unable to explain why some users discontinue IT/IS use after initially accepting it (that is, the acceptance-discontinuance anomaly).

User-based research and development strategy suggests that vendor services and products have to meet users' expectations. In this regard, field surveys are an important means for mobile device manufacturers to address the principal focus of the users. Different users may demonstrate similar preferences for the same mobile application.

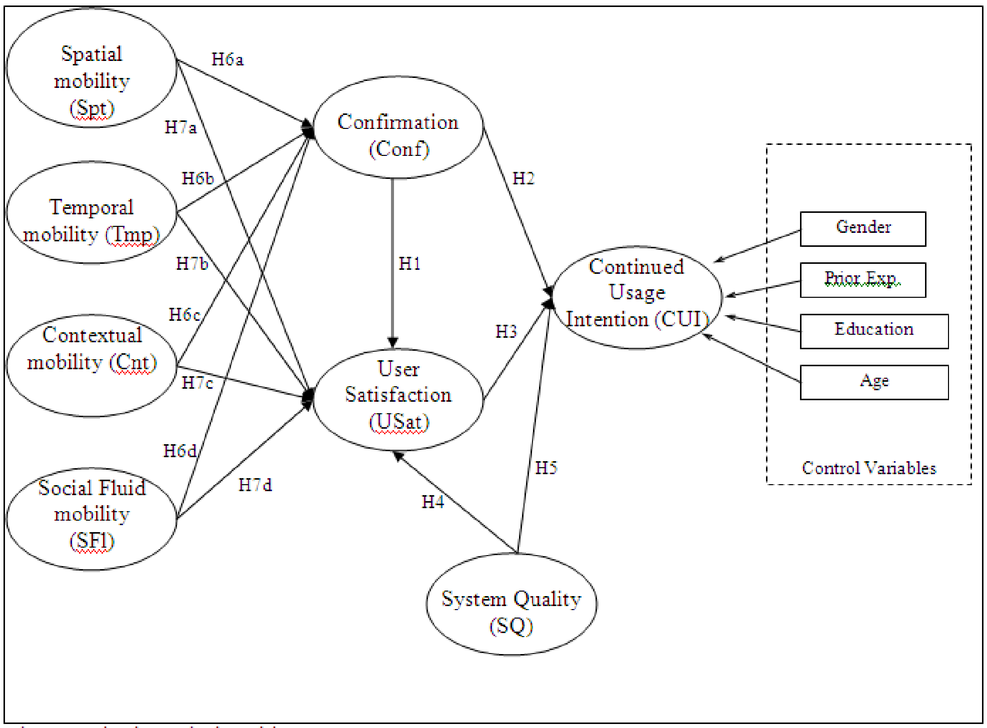

Figure 1: The theoretical model

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WAVELET-BASED WARPING TECHNIQUE FOR MOBILE DEVICES

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ABSTRACT

The role of digital images is increasing rapidly in mobile devices. They are used in many applications including virtual tours, virtual reality, e-commerce etc. Such applications synthesize realistic looking novel views of the reference images on mobile devices using the techniques like image-based rendering (IBR). However, with this increasing role of digital images comes the serious issue of processing large images which requires considerable time. Hence, methods to compress these large images are very important. Wavelets are excellent data compression tools that can be used with IBR algorithms to generate the novel views of compressed image data. This paper proposes a framework that uses wavelet-based warping technique to render novel views of compressed images on mobile/ handheld devices. The experiments are performed using Android Development Tools (ADT) which shows the proposed framework gives better results for large images in terms of rendering time.

KEYWORDS

Image-based rendering, 3D image warping, Wavelet image compression, Novel view generation of compressed images on android-based mobile devices.

1. INTRODUCTION

For mobile devices with limited screen size, processing of large images takes considerable amount of time. This is where compression techniques come into act. Various compression techniques have been available, but in the past few years, wavelets have shown to be more efficient than many other methods [1]. The power of wavelets is Multi-Resolution Analysis (MRA) which allows representing different levels of detail of images. The Haar wavelet [2] is one of the simplest wavelet transforms which can be used to transform large images into considerably smaller representations that then can be processed on mobile/ handheld devices at higher speeds. This paper proposes a framework to render novel views of compressed images using Haar wavelet based 3D warping technique on mobile devices. Such a framework is particularly useful in visualization of large images on mobile/ handheld devices at interactive rates. The paper is organized as follows: Section 2 gives an overview of Haar wavelet transformation for lossy image compression; Section 3 explores the image-based 3D image warping technique; Section 4 describes the implementation of the proposed framework for mobile devices using Android Development Tools (ADT); Section 5 provides the experimental results and performance comparison; and Section 6 presents the conclusion.

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2. HAAR WAVELET TRANSFORM FOR IMAGE COMPRESSION

Although wavelets have their roots in approximation theory and signal processing, they have recently been applied to many problems in computer graphics like image editing, image compression, animation, global illumination etc [3]. Over the past few years, various wavelet-based image compression schemes like Discrete Cosine Transform (DCT) [4], Haar transform [2], Daubechies transform [5] [6] etc. are available, each having their own representation and optimization procedures. Among these techniques, the Haar transform is one that has been mainly used due to its low computing requirements.

An image is a matrix of pixel (or intensity) values; therefore, it can be thought of as two dimensional signals, which change horizontally and vertically. Thus, 2D haar wavelet analysis is performed on images using the concepts of filters. Filters of different cut-off frequencies analyze the image at different scales. Resolution is changed by filtering, the scale is changed by up-sampling and down-sampling. First horizontal filtering decomposes the image into two parts, an approximation part (low frequency) and a detail part (high frequency). Then vertical filtering divides the image information into approximation sub-image, which shows the general trend of pixel values; and three detail sub-images, which show the horizontal, vertical and diagonal details or changes in the image. At each level, four sub-images are obtained. Fig. 1 shows haar wavelet transform that divides N x N image into 4 sub-images. Each piece has dimension (N/2) x (N/2) and is called Approximation (represented by LL), Horizontal details (represented by HL), Vertical details (represented by LH) and Diagonal details (represented by HH) respectively. To get the next level of decomposition, haar wavelet transform is applied to the approximation sub-image.

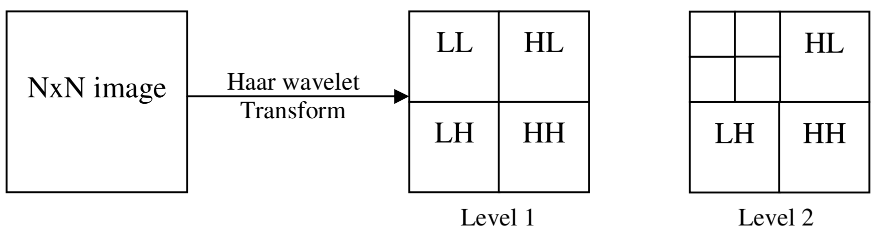

Figure 1. Haar wavelet transform of an image

To get a better idea about the implementation of this wavelet in image compression, consider a 512 x 512 pixels grayscale image of the woman (elaine_512.gif) as shown in Fig. 2. By applying the Haar wavelet transform we can represent this image in terms of a low-resolution image and a set of detail coefficients (Fig. 2). The detail coefficients can be used for the reconstruction of the original image.

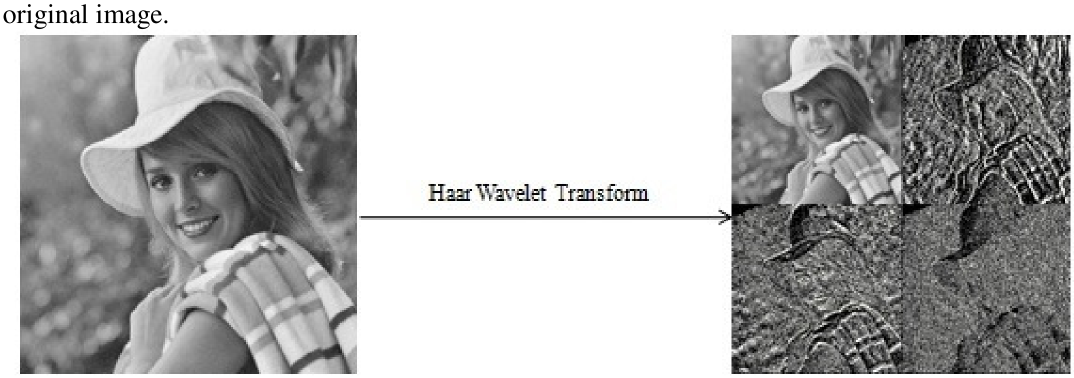

Figure 2. Haar wavelet transform on grayscale image

In computer graphics, we can use the averaging and differencing technique as the application of Haar wavelet to compress the image. The low-pass (average) filter and high-pass (difference) filter are defined as:

$$A = (a+b)/2 \; and \; D = (a-b)/2 \qquad (1)$$

where a and b are pixel values of the image. Taking one row at a time, first apply averaging and differencing technique for each pair of pixel values. After treating all rows, apply the same procedure for each column of the image matrix. This produces a matrix containing approximation part (storing the general trend of the image) and detail part (containing most values close to zero). For example, consider the upper left 8 x 8 section of grayscale image in Fig. 2. Fig. 3 shows the resultant matrix by applying averaging and differencing procedure on this matrix.

$$\begin{bmatrix} 190 & 190 & 190 & 190 & 190 & 192 & 192 & 192 \\ 190 & 190 & 190 & 190 & 190 & 192 & 192 & 192 \\ 190 & 190 & 190 & 190 & 190 & 192 & 192 & 192 \\ 190 & 190 & 190 & 190 & 190 & 192 & 192 & 192 \\ 190 & 190 & 190 & 190 & 190 & 192 & 192 & 192 \\ 190 & 190 & 190 & 190 & 190 & 192 & 192 & 192 \\ 190 & 190 & 190 & 190 & 190 & 192 & 192 & 192 \\ 190 & 190 & 190 & 190 & 190 & 192 & 192 & 192 \end{bmatrix} \xrightarrow[\text{Transform}]{\text{2D Haar Wavelet}} \left[\begin{array}{cccc|cccc} 190 & 190 & 191 & 192 & 0 & 0 & -1 & 0 \\ 190 & 190 & 191 & 192 & 0 & 0 & -1 & 0 \\ 190 & 190 & 191 & 192 & 0 & 0 & -1 & 0 \\ 190 & 190 & 191 & 192 & 0 & 0 & -1 & 0 \\ - & - & - & - & - & - & - & - \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{array}\right]$$

Figure 3. Haar wavelet transform on image matrix

In images, low frequency (changing slowly over the image) information is usually a lot more than high frequency (quickly changing) information. Due to this, most of the values resulting from the high-pass filter are close to 0. The more of these values which are close to 0, the more affectively the image can be compressed.

Grayscale image consists of a single matrix, but for RGB images, there are 3 matrices of same size to represent three colors: red, blue and green. Therefore, we apply Haar wavelet transform on 3 different matrices separately. Fig. 4 shows the approximation part of 512 x512 pixels RGB image (Lena.bmp) after applying one level Haar wavelet transform which is close to original image.

Original Image (512 x 512) Compressed Image (256 x 256)

Figure 4. Haar wavelet transform to compress RGB image

3. 3D IMAGE WARPING

3D image warping is an image-based rendering (IBR) algorithm that allows a 2D reference image to be viewed from a different view position and/ or orientation [7]. The reference image contains color information as well as depth information for each pixel. The processing required for IBR is independent of scene complexity but instead dependent on screen resolution. As such it is especially suited for rendering on low-end mobile devices with small screen size. The central computational component of 3D image warping technique is a mapping function, which maps pixels in the reference images to their coordinates in the target image according to the following equation:

$$x_d = \delta(x_r) P_d^{-1}(C_r - C_d) + P_d^{-1}\,\mathrm{P_r}\,x_r \quad (2)$$

where $\boldsymbol{x_d}$ is the result of mapping of the point $\boldsymbol{x_r}$ on reference image to the desired image, whose centers of projection are C_r and C_d respectively. $(C_r - C_d)$ is a vector between the two centers of projection. P_r and P_d represent the pinhole camera viewing matrices for reference and desired image respectively. P_d is computed each time the user changes orientation or position of camera to generate a novel view of the reference image. The quantity $\delta(x_r)$ is called the generalized disparity for point x_r which is inversely proportional to the depth. 3D warping requires that this value to be known for all points in the reference image.

Mapping using 3D Warping equation is not one-to-one. Therefore we must resolve visibility. McMillan describes such an algorithm to calculate a reference image traversal order that ensures correct visibility processing using epipolar geometry [8]. The algorithm is based on epipolar point which is the projection of the viewpoint of a novel view onto the reference image. This epipole divides the reference image's domain into sheets. The warping order for each sheet can be determined using the type of epipolar point (positive or negative). If the epipole is positive, then the traversal must move from the edge of the image towards the epipole. Otherwise for negative epipole, the traversal must move from the epipole towards the edge of the image.

4. PROPOSED FRAMEWORK FOR MOBILE DEVICES

In this section, we propose a framework that uses wavelet-based warping technique to render novel views of large images on mobile/ handheld devices. The proposed framework is based on 3D image warping technique. Further, it makes use of restructured warping order cases and scan line coherency proposed by Walia and Verma [9] and Haar wavelet transform to decompose large images. For a level-one transform, this creates four sub images (one approximation and three details). However, we ignore the three detail images and simply warp the approximation image. This reduces image size to one half to its original size along the width as well as height. Similarly, the depth image is also reduced to one half to its original size along the width as well as height by using the Haar wavelet transform. This results in making the mapping from reference image to desired image efficient while generating the novel views, as the rendering time of the warping technique is directly proportional to the image size rather than image complexity. In mobile/ handheld devices where hardware resources are limited, this improves the interactivity and performance. Fig. 5 shows the flowchart of the proposed framework.

Fig. 6 summarizes the algorithm of the proposed framework for mobile devices. The input for this framework is reference and disparity image of size N*N with camera parameters (like center of projection for reference view $\mathbf{C_r}$, center of projection for desired view $\mathbf{C_d}$, and Projection Matrix **P**). The output for this framework is a novel view of the compressed reference image. The novel view is then rendered on the mobile screen. The proposed framework is implemented using Android Development Tools (ADT) version 22.3; which can run on any mobile device that runs

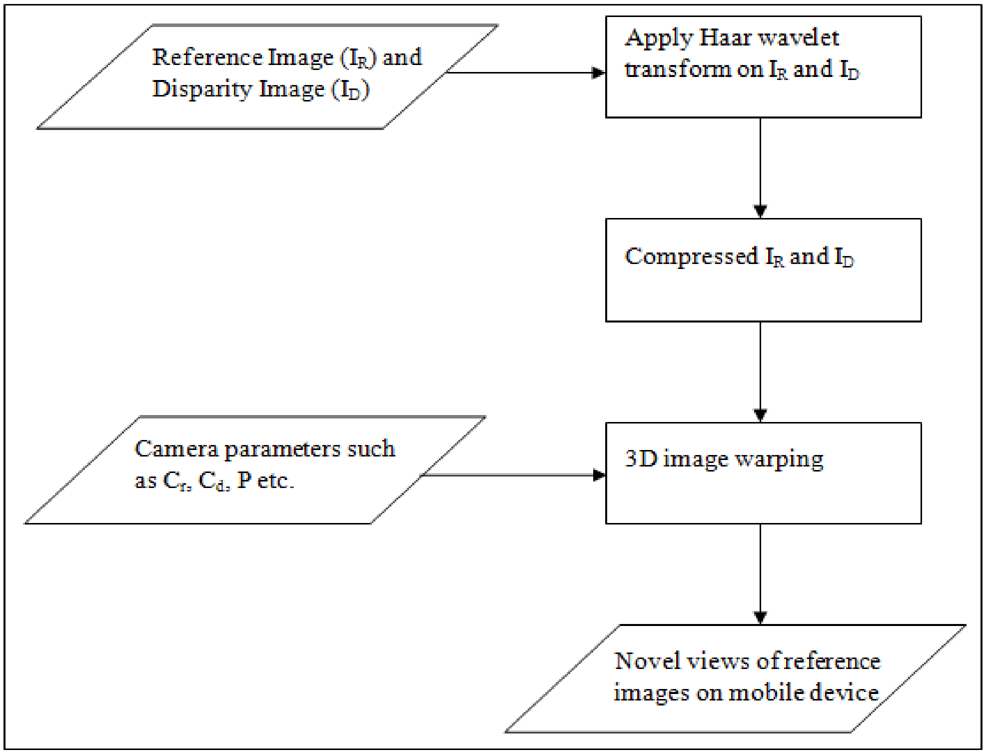

Figure 5. Flowchart of Proposed Framework

on Android OS. User can navigate through the touch screen of the mobile device to change the orientation and position of the camera. Whenever the user performs the navigation, the new values for the camera parameters are computed and the procedure to render the new view is started. The user can also perform zoom-in, zoom-out and reset operations or to change the reference image itself through the DPAD buttons on the mobile device.

Algorithm: Wavelet-based warping framework for mobile devices using ADT.
Input: Reference image, Disparity image, Camera parameters (C_r, C_d, P etc.).
Output: Novel views of compressed reference image.
begin
1: Read Reference Image, I_R together with its Disparity Image, I_D and corresponding camera parameters such as C_r, C_d, P etc.
2: Invoke *Haar*(I_R) to decompose reference image into 4 sub-images.
3: Invoke *Haar*(I_D) to decompose disparity image into 4 sub-images.
4: Take the approximation part and reject the detail parts of reference and disparity images.
5: Determine the epipolar point which divides the compressed reference image into sheets.
6: Render sheets using epipolar geometry to generate the novel view.
7: User can use DPAD buttons on the mobile device to perform zoom-in, zoom-out and reset operations or to change the reference image itself. Goto step 2.
8: Whenever the user performs the navigation through the touch screen, new values for the camera parameters are computed and goto step 2.
End

(a)

Procedure: Haar(Image I)
begin
1: Separate RGB components of the image I.
2: Invoke *HWT(R)* to perform Haar Wavelet Transform on RED component of the image.
3: Invoke *HWT(G)* to perform Haar Wavelet Transform on GREEN component of the image.
4: Invoke *HWT(B)* to perform Haar Wavelet Transform on BLUE component of the image.
5: Combine RGB components of the image.
end

(b)

Procedure: HWT(Image Component Matrix)
begin
1: For each row in the image matrix:
   a) Find the average of each pair of values.
   b) Find the difference of each pair of values.
   c) Fill the first half with averages.
   d) Fill the second half with differences.
   e) Select the first half and repeat the process until it has one element.
2: For each column in the image matrix:
   a) Find the average of each pair of values.
   b) Find the difference of each pair of values.
   c) Fill the first half with averages.
   d) Fill the second half with differences.
   e) Select the first half and repeat the process until it has one element.
3: This produces the updated image matrix containing approximation and detail parts.
end

(c)

Figure 6. Proposed Framework (a) Complete algorithm (b) Procedure Haar (c) Procedure HWT

5. Experimental Results And Discussion

The proposed framework has been implemented using *Java Platform Standard Edition 1.6 (update 21) and Android Development Tools (ADT) version 22.3*. The experiments have been conducted using Android Virtual Device (AVD) emulator on a machine having 2.5 GHz Intel(R) Core(TM) i5 CPU and 4.0 GB RAM. A set of images taken from a dataset of images [10] has been used in our experiments. Fig. 7 shows a subset of images along with their gray scale images (having depth information).

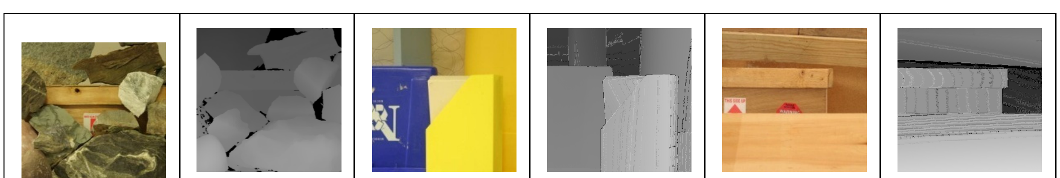

Image1 (512 x 512 pixels) | Image2 (512 x 512 pixels) | Image3 (512 x 512 pixels)

Figure 7. Images (with their depth information)

In the setup discussed above, experiments have been conducted to evaluate the performance of proposed framework in Android environment on a set of images shown in Fig. 7. The ADT can be used to define AVD (Android Virtual Device) emulators that enable us to simulate the mobile environment on a PC. Fig. 8 shows the output of the proposed rendering framework in the AVD emulator having screen size 3.2" with 512 MB RAM.

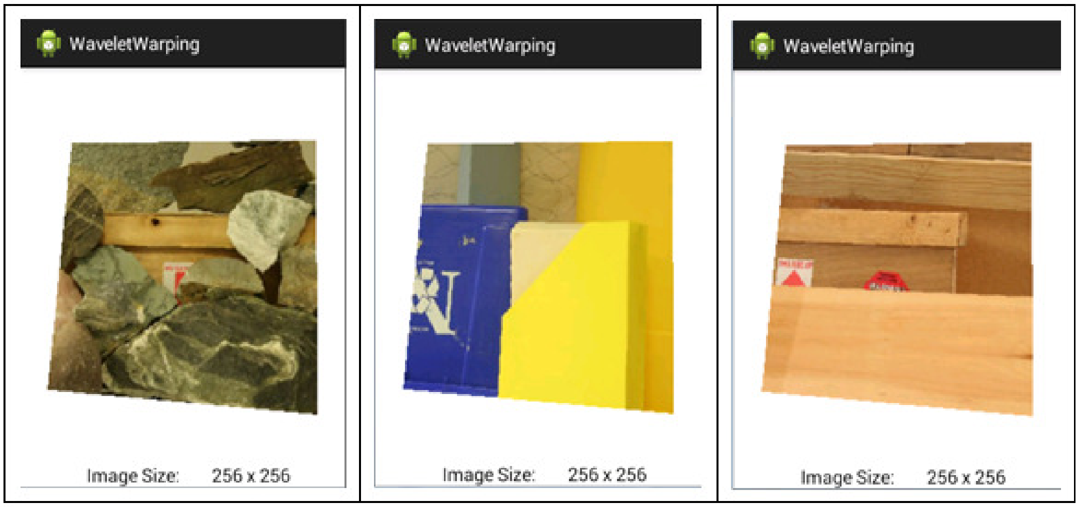

Figure 8. Rendering using proposed framework in AVD emulator

Table 1 gives the rendering times (in milliseconds) of the different images using the proposed framework and its comparison with the warping framework proposed by [9] using ADT. The experimental results show that the proposed framework gives better results for compressed images in terms of rendering time. Further as shown in Fig. 8, the compressed rebuilt image is close to the original image.

Table 1. Rendering time comparison of images shown in Fig. 6

Images	**Rendering time using warping framework [9] (in ms)**	**Rendering time using wavelet-based warping framework (in ms)**
Image1	3490	2278
Image2	3454	2293
Image3	3462	2232

6. CONCLUSION

In this paper we propose a wavelet-based warping framework to render novel views of a reference image on mobile devices. By applying the Haar wavelet transform we represent the reference and disparity images in terms of low-resolution images and a set of detail coefficients. By ignoring the detail coefficients and simply warping the approximation image we get the novel view of the reference image. As the rendering time of the warping technique is directly proportional to the image size rather than image complexity, this improves the rendering time. The framework is implemented with Android Development Tools (ADT) and its performance is evaluated. The experimental results show the proposed framework gives better results for compressed images in terms of rendering time. Further, the compressed rebuilt image is close to the original image.

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ADAPTIVE TRILATERAL FILTER FOR IN-LOOP FILTERING

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ABSTRACT

High Efficiency Video Coding (HEVC) has achieved significant coding efficiency improvement beyond existing video coding standard by employing several new coding tools. Deblocking Filter, Sample Adaptive Offset (SAO) and Adaptive Loop Filter (ALF) for in-loop filtering are currently introduced for the HEVC standard. However, these filters are implemented in spatial domain despite the fact of temporal correlation within video sequences. To reduce the artifacts and better align object boundaries in video, a proposed algorithm in in-loop filtering is proposed. The proposed algorithm is implemented in HM-11.0 software. This proposed algorithm allows an average bitrate reduction of about 0.7% and improves the PSNR of the decoded frame by 0.05%, 0.30% and 0.35% in luminance and chroma.

KEYWORDS

HEVC, Trilateral Filter and In-Loop Filter.

1. INTRODUCTION

HEVC is the new video coding standard developed by the joint collaboration of the ITU-T Video Coding Experts Group (VCEG) and the ISO/IEC Moving Picture Experts Group (MPEG). The main aim of the HEVC is improving the compression efficiency of the H.264/AVC standard by almost 50% and maintaining the same computational complexity. Many coding tools are included to reduce the distortion between the original frames and decoded frames produced by the lossy coding.

The name loop filtering reflects that the filtering is done by removing the blocking artifacts [1].H.264/AVC includes an in-loop Deblocking filter. HEVC employs a Deblocking filter similar to the one used in H.264/AVC but expands an in-loop processing by introducing two new tools: SAO and ALF. These techniques are implemented to reduce the distortion introduced by the encoding process(prediction, transform, and quantization). By including these filtering techniques, the pictures will serve as better references for motion- compensated prediction since they have less encoding distortion.

Over the past several years many algorithms have been proposed for reducing the blocking artifacts and the bit rate [2] – [5]. These algorithms can be categories into three types: first type is a post processing algorithm for removing blocking artifacts for highly compressed images in the DCT domain [2], second one reduces the blocking artifacts carried out at encoding schemes and third one reduces the temporal redundancy of ALF parameters by reusing the prior transmitted filter parameters [3]. In [4],a strong filter is selectively applied to blocks having small artifacts to

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avoid harmful side effect of filtering. A weak filter is applied to the other blocks to slightly correct them. In [5],an adaptive in-loop bilateral filter selecting the optimal filter parameters, based on the image characteristics, is proposed to minimise the Lagrangian Rate-Distortion.

In this paper, we propose an algorithm to reduce the bit rate and improve the video quality by combining a trilateral filter and adaptive filter together, evaluate the effect of proposed algorithm on the quality of the output and compare their results to the evaluated results of the original algorithm of HEVC for various quantization parameters.

The rest of the paperis organized as follows: Section II describes the adaptive loop filtering. Section III describes the trilateral filter. Section IV describes the proposed algorithm. Finally, the experimental results and conclusion are shown in sections V and VI.

2. HEVC ADAPTIVE LOOP FILTERING

This section describes ALF core techniques employed in the final ALF version in HM-11.0. The filter includes Wiener filter, filter shapes, and coefficient coding. The Wiener filter minimizes the mean square error between the desired samples and the filtered samples. The desired samples are the original picture. The to-be-filtered samples are the output picture of SAO. The filtered samples are the output picture of ALF.

In [1], an ALF is applied to the reconstructed signal after the de-blocking filter and SAO. The filter is adaptive in the sense that the coefficients are signalled in the bit stream and can therefore be designed based on image content and distortion of the reconstructed picture. The filter is used to restore the reconstructed picture such that the mean-squared error between the source picture and the reconstructed picture is minimized.

Test Model HM-3.0 uses a single filter shape which is a cross overlaid on a 3 x 3 square with nine coefficients, to be encoded in the bit stream. The number of taps in the filter is greater than nine due to symmetry; however, every picture may not need all the nine taps as in HM-7.0 [6]. This test model has different filter square shapes 5X5, 7X7 and 9X9, where these shapes can be selected for different pictures. In HM-6.0 and HM-7.0, number of coefficients is reduced to half by changing the ALF from square to diamond shape. The combination of 9X7-tap cross shape and 3X3-tap rectangular shape generates the filter shape of ALF in HM-7.0.The Filter coefficients are derived by solving Wiener-Hopf equation [6].ALF in HM7.0 reduces the number of coefficient by half which in turn reduces the number of multiplications by half, which significantly reduces the chip area for ALF.

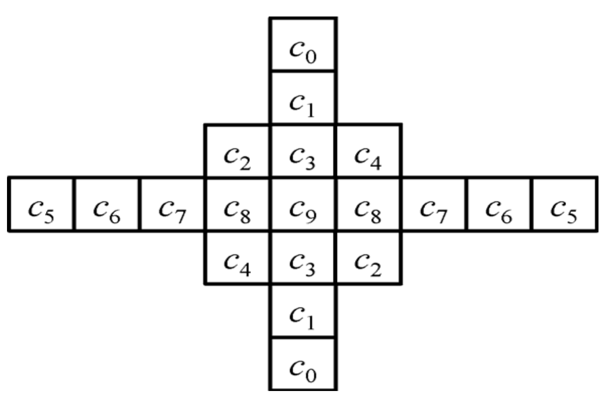

Figure 1: Filter shape of ALF in HM-6.0 and HM-7.0.

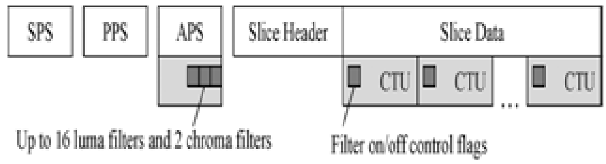

Figure 2: Locations of ALF parameters in the bit stream.

Syntax Design

There are two types of coded information for ALF: filter coefficient parameters and filter on/off control flags. As shown in Fig. 2, the filter coefficient parameters are located in a picture-level header called APS, and the filter on/off control flags are interleaved in slice data with CTUs. The filter coefficient parameters include picture-level on/off control flags for three color components, number of luma filters (i.e., class/region merging syntax elements for BA/RA), and corresponding filter coefficients. Up to 16 luma filters, one Cb filter, and one Cr filter per picture can be signalled. Filter on/off control flags are used to provide better local adaptation. In addition to the picture-level filter on/off control flags in APS, there are also slice-level and CTU-level filter on/off control flags. In slice header, similarly, filter on/off control flags for three color components are coded. The signalling of slice-level filter on/off control flags can solve a slice parsing problem when the referenced APS of the slice is lost [7]. If the slice-level on/off control flag indicates ALF-on, CTU-level filter on/off control flags are interleaved in slice data and coded with CTUs; otherwise, no additional CTU-level filter on/off control flags are coded and all CTUs of the slice are inferred as ALF-off.

APS was removed from HEVC standard after HM-8.0.

As APS is removed the related syntax elements of filter parameters in slice header ALF is implemented.

Trilateral Filter

An image is defined by f(x) $\in R^n$(n = dimensionality), where x $\in \Omega$ is the pixel position in image domain Ω. Generally speaking, an *n*-D (*n*-dimensional) pixel-discrete image has an image domain defined as,$\emptyset \subset \Omega \subseteq X_n \subset N^n$(*Xn* is our maximum discrete index set of the image domain in dimension *n*). A smoothing operator will reduce an image to a smoothed version of itself, specifically S(*f*) = s, where s is in the same image domain as *f*. To introduce the trilateral filter, we must first define the bilateral [8] case; we will then go on to define the traditional trilateral filter using this notation.

The trilateral filter is a "gradient-preserving" filter [8]. It aims at applying a bilateral filter on the current plane of the image signal. The trilateral case only requires the specification of one parameter σ_1. At first, a bilateral filter is applied on the derivatives of f (i.e., the gradients):

$$g_f(x) = \frac{1}{k_\nabla}\int_\Omega \nabla f(x+\mathbf{a})\cdot w_1(\mathbf{a})\cdot w_2(\|\nabla f(x+\mathbf{a}) - \nabla f(x)\|)d\mathbf{a}$$

$$k_\nabla(x) = \int_\Omega w_1(\mathbf{a})\cdot w_2(\|\nabla f(x+\mathbf{a}) - \nabla f(x)\|)d\mathbf{a}$$

To approximate$\nabla f(x)$, forward differences are used, and more advanced techniques (e.g., Sobel gradients, 5-point stencil) are left for future studies. For the subsequent second bilateral filter, suggested the use of the smoothed gradient $g_f(x)$ [instead of $\nabla f(x)$ for estimating an approximating plane

$$p_f(x, \mathbf{a}) = f(x) + g_f(x) \cdot \mathbf{a}$$

Let $f_\nabla(x, \mathbf{a}) = f(x + \mathbf{a}) - p_f(x, \mathbf{a})$. Furthermore, a neighbour-hood function

$$N(x + \mathbf{a}) = \begin{cases} 1 & if\ |g_f(x + \mathbf{a}) - g_f(x)| < c \\ 0 & otherwise \end{cases}$$

is used for the second weighting. Parameter c specifies the adaptive region and is discussed further below. Finally,

$$s(x) = f(x) + \frac{1}{k_\nabla(x)} \int_\Omega \nabla f(x, \mathbf{a}) \cdot w_1(\mathbf{a}) \cdot w_2(\nabla f(x, \mathbf{a})) \cdot \mathrm{N}(x, \mathbf{a}) d\mathbf{a}$$

$$k_\nabla(x) = \int_\Omega w_1(\mathbf{a}) \cdot w_2(\nabla f(x, \mathbf{a})) \cdot \mathrm{N}(x, \mathbf{a}) d\mathbf{a}$$

The smoothed function *s* equals $S_{TL}(f)$.

Again, w_1 and $w_2$are assumed to be Gaussian functions, with standard deviations σ_1 andσ_2, respectively. The method requires specification of parameter σ_1 only, which is at first used to be the diameter of circular neighbour-hoods at x in f; let $\overline{g_f}(x)$be the mean gradient of f in such a neighbourhood. The parameter for w_2 is defined as follows:

$$\sigma_2 = \beta \cdot \left| \max_{x \in \Omega} \overline{g_f}(x) - \min_{x \in \Omega} \overline{g_f}(x) \right|$$

(β =0:15 was chosen). Finally,$c = \sigma_2$.

3. PROPOSED ALGORITHM

There are three in-loop filtering techniques in HEVC; namely, the de-blocking filtering, the Sample Adaptive Offset (SAO) and the Adaptive Loop Filter (ALF). After the details of these filters in the previous sections, we design the proposed filter in in-loop filtering process.

Boundary Block Detection

Trilateral filter works in the context of block-based processing. The trilateral filter might introduce other blocking artifacts if it is applied to all the blocks in a frame, so it is only applied to blocks in object boundaries. This is called region-based filtering. The standard deviation of the block is used to detect where the boundary block. Non-boundary blocks usually consist of homogeneous pixel values and have a smaller variance. When the standard deviation of a block exceeds a pre-defined value, the trilateral filtering is performed and the standard deviation for an NXN block is:

$$\mathrm{STD} = \mathrm{Sqrt}\left\{\frac{1}{\mathrm{N} \times \mathrm{N}} \sum_{\mathrm{i}=0}^{\mathrm{N}-1} \sum_{\mathrm{j}=0}^{\mathrm{N}-1} [\mathrm{I}(\mathrm{i},\mathrm{j}) - \mathrm{Mean_{blk}}]^2\right\}$$

Where N is the block size, I(i,j) is the pixel intensity, and Mean is the mean of the block.

In-Loop Filtering

After the details of ALF and trilateral filter in SECTION II, it is now essential to define how to combine these filters in the HEVC in-loop filtering process. As described in the introduction. The trilateral filter is "gradient-preserving" filter suited to remove the blocking artifacts whereas the Adaptive loop filter is more targeted to reduce the bit-rate. Therefore, it is appropriate to combine these two filters by selecting, for each image block in the reconstructed frame. This is the main idea behind the proposed algorithm whose processing considered each block along with the de-blocking filter. The filtering reduces the bit-rate and improves the PSNR values and is not complicated when compared with other algorithms. Now the procedure is detailed in steps by supposing a input frame F into the in-loop filter. The performed steps are:

1. Partition F into block size of B
2. Using the standard deviation of a block detect the object boundaries
3. Over the object boundary perform TLF to obtain F^{TLF}
4. Perform DBF over the remaining blocks of the frame to obtain F^{DBF}
5. Finally the combined frame F^{TDBF} is obtained
6. Over the whole frame F^{TDBF} perform ALF to obtainF^{TDALF}.

In this algorithm by considering the region characteristics of the block only the block boundaries are filtered by trilateral filter. Therefore, we adopt the quad-tree structure of LCU in HEVC. For every CUs in LCU, we check whether its standard deviation is above a certain threshold. If the condition is met, we perform the trilateral filtering in this block. Later ALF is performed over the whole frame. The overall flow chart of the proposed in-loop filter for HEVC is shown in Figure 3

Figure 3: Flow chart of the proposed algorithm.

4. Experimental Results

In this paper, the proposed method is implemented on HM-11.0 and the results are obtained for both the modified HM11.0 and the original one. For each video sequence, the quantization parameters are 32, 38 and 42. Five frames in the test sequence are encoded. Figures 4 and 5 show the PSNR for different bit rates. Figure 6 compares the subjective video quality (better quality can be shown on a screen).

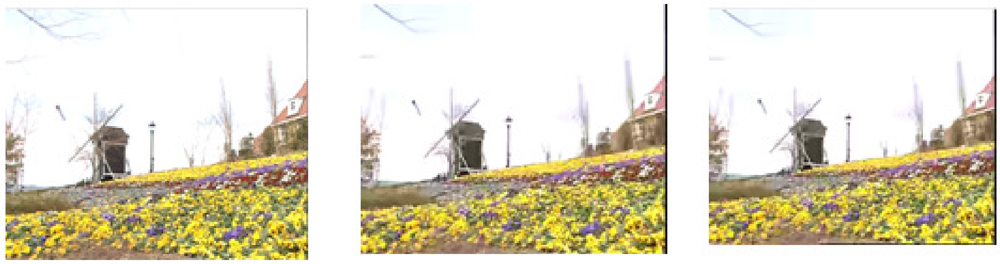

Figure 6: (a) input picture (b) reconstructed picture using original software (c) reconstructed picture using proposed software

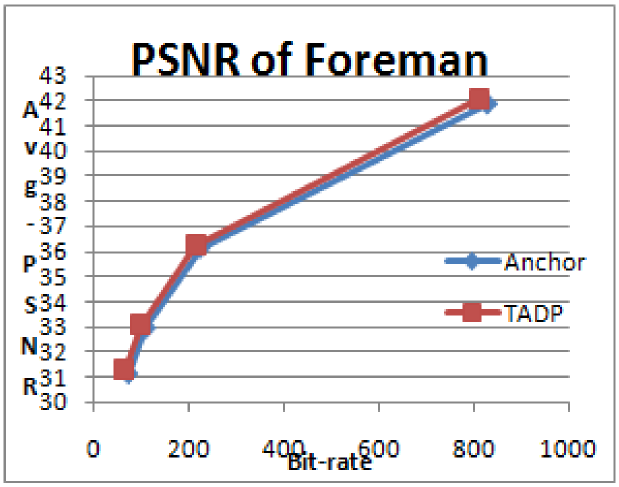

Figure 4:PSNR for different bit rates using Foreman.

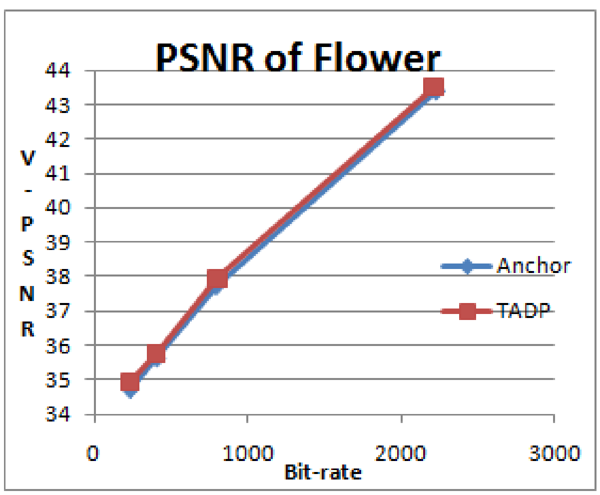

Figure 5: PSNR for different bit rates using Flower.

Table 1: Flower YUV.				
QP	Bitrate changes %	Y-PSNR	U-PSNR	V-PSNR
32	0.69	0.03	0.10	0.18
38	0.66	0.05	0.21	0.27
42	0.65	0.07	0.34	0.35

Table 1: Bit-rate and PSNR changes for test sequence

Table 2: Foreman YUV.				
QP	Bitrate changes %	Y-PSNR	U-PSNR	V-PSNR
32	0.67	0.05	0.245	0.291
38	0.65	0.039	0.338	0.349
42	0.63	0.035	0.157	0.156

Table 2:Bit-rate and PSNR changes for test sequence

Tables 1 and 2 show that the proposed algorithm reduces the bit rate by 0.7% and improves the PSNR values by 0.05%, 0.30 % and 0.35 %in luminance and chroma. Improvement is more significant on low resolution than the high resolution video sequences.

5. CONCLUSION

In this paper, the main aim of proposing a new adaptive trilateral filter for in-loop filtering is to reduce the bit-rate and improve the PSNR values. The simulation results show that the proposed algorithm improves rate distortion performance and reduces the ringing artifacts introduced by the use of large transform block sizes and, therefore, it also improves the perceived video quality. Moreover, proposed algorithm allows an average bitrate reduction of about 0.7% and improves the PSNR of the decoded frame by 0.05%, 0.30% and 0.35% in luminance and chroma.

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A CLOUD SERVICE SELECTION MODEL BASED ON USER-SPECIFIED QUALITY OF SERVICE LEVEL

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ABSTRACT

Recently, it emerges lots of cloud services in the cloud service market. After many candidate services are initially chosen by satisfying both the behavior and functional criteria of a target cloud service. Service consumers need a selection model to further evaluate nonfunctional QOS properties of the candidate services. Some prior works have focused on objective and quantitative benchmark-testing of QOS by some tools or trusted third-party brokers, as well as reputation from customers. Service levels have been offered and designated by cloud service providers in their Service Level Agreement (SLA). Conversely, in order to meet user requirement, it is important for users to discover their own optimal parameter portfolio for service level. However, some prior works focus only on specific kinds of cloud services, or require users to involve in some evaluating process. In general, the prior works cannot evaluate the nonfunctional properties and select the optimal service which satisfies both user-specified service level and goals most either. Therefore, the aim of this study is to propose a cloud service selection model, CloudEval, to evaluate the nonfunctional properties and select the optimal service which satisfies both user-specified service level and goals most. CloudEval applies a well-known multi-attribute decision making technique, Grey Relational Analysis, to the selection process. Finally, we conduct some experiments. The experimental results show that CloudEval is effective, especially while the quantity of the candidate cloud services is much larger than human raters can handle.

KEYWORDS

Cloud Service, Cloud Service Selection, Multi-attribute Decision Model, Quality of Service, Cloud Computing

1. INTRODUCTION

Emerging cloud computing and its application emphasize on lower Total Cost of Ownership (TCO), that pay as you go for the cloud services. It makes a user through the application of cloud services to reduce TCO and energy consumption. A cloud interactive model over Internet is composed of two parts: a cloud client and a cloud service. Common applications of a cloud client are such as web pages and mobile applications. As for categories of cloud services, NIST has defined three cloud service models: Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) [1].

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Recently, it emerges lots of cloud services in the cloud service market. Enterprises need to select suitable cloud services effectively to meet the requirements of an enterprise information systems and their integration. If a suitable cloud service could be integrated into an enterprise information system, the quality of the information system would be better than one with an un-suitable cloud service. Khezrian et al. [2] deem that two significant tasks in the process of a selection model are selection and ranking in which every solution for them is affected directly on description of services. During describing a service, three properties have to be considered: behavior, functional, and nonfunctional. The candidate services are initially chosen by satisfying both the behavior and functional criteria of a target cloud service. As there are often many cloud services that meet the functional and behavior requirements, the cloud service selection uses some criteria to select the optimal service. However, in real world practice, there are too large a number of possible candidate cloud services to select manually. Thus, service consumers need a selection model to further evaluate nonfunctional properties of the candidate services, such as Quality of Service (QOS), price and reputation.

Besides, service levels have been offered and designated by many cloud service providers in their Service Level Agreement (SLA). Conversely, in order to meet user requirement, it is important for users to discover their own optimal parameter portfolio for service level. It also depends on selection criteria of cloud services. And, the criteria of cloud service have dynamic, invisible, variant, subjective and vague characteristics. Therefore, it is a multi-attribute decision-making problem about discovering the optimal parameter portfolio. Still, cloud providers and third-party brokers have not had the selection and recommendation mechanisms. The criteria in previous researches focus on benchmarks by a trusted third-party broker, such as CloudHarmony [3], based on objective and quantitative testing of QOS, as well as reputation from customers. The criteria in previous researches focus on benchmarks by some tools (i.e. CloudCmp [4] and vCenter Hyperic [5]), or third-party brokers (i.e. CloudHarmony) based on objective and quantitative testing of QOS, as well as reputation from customers.

However, some prior works [6, 7] focus only on specific kinds of cloud services, or require users to involve in some evaluating process [7, 8]. In general, the prior works cannot evaluate the nonfunctional properties and select the optimal service which satisfies both user-specified service level and goals most either. Therefore, based on user-specified QOS requirement for service level, and the objective and quantitative benchmarks, the aim of this study is to propose a new cloud service selection model, CloudEval (**Cloud Eval**uator), to evaluate the nonfunctional properties and select the optimal service which satisfies both user-specified service level and goals most. CloudEval applies a well-known multi-attribute decision making technique, i.e. Grey Relational Analysis, to the selection process.

The remainder of this paper is organized as follows. Section 2 reviews the related research work. Section 3 describes CloudEval. Section 4 presents the experiments and an analysis of the results. Finally, Section 5 draws conclusions.

2. RELATED WORK

2.1. Selection Models

In view of the limits of the prior works that we have mentioned above, now we explained about why they cannot evaluate the nonfunctional properties and select the optimal service which satisfies both user-specified service level and goals most. First, some prior works [6, 7] focus only on specific kinds of cloud services (such as SaaS, web server service, or cloud storage service) neglect wider scope benchmarks from the broker, and financial or service credit in SLA from providers need to be further quantified and integrated during the selection. Secondly, some prior works related to AHP [7] or Fuzzy methods [8] with aggregated subjective and objective criteria need users to participate the evaluating process. They require the users to specify a preference manually for each decision alternative on each criterion. Thirdly, prior works [7, 8] rank the priorities of the candidate service list of alternatives calculated on only goals rather than calculated on both goals and user-specified service level.

2.2. Benchmarks and Attributes of Cloud Services

Benchmarking techniques have been used to measure the performances of the system components of a cloud service. The system components can be CPUs, storage services, server services, network and applications running in physical and virtual environment. Li et al. [4] indicate that recent benchmarking measurements are limited in scope; none of them cover enough of the dimensions (e.g., compute, storage, network, scaling) to yield meaningful conclusions. Further, some of the measurement methodologies do not extend to all providers, for example, they would not work for PaaS providers. Recently, CloudHarmony is a popular third-party trusted broker which offers both IaaS and PaaS of public cloud monitoring and benchmarking service [3]. The attributes of cloud service data that CloudHarmony has offered are availability, response time, system performances and network performances. As CloudHarmony has covered enough of the dimensions for measuring a cloud service, we adopt its cloud service data related to the attributes as part of the input data source of our selection model, CloudEval.

The criteria in prior works focus on benchmarks by some tools or third-party brokers based on objective and quantitative testing of QOS, as well as reputation from customers. The attributes of selection criteria that Menzel & Ranjan [7] have proposed used in their framework, CloudGenius, are price, maximum network latency, average network latency, performance, uptime (i.e. availability) and popularity (i.e. reputation). The Performance attribute has three subattributes, CPU, RAM and Disk performance. The attributes of criteria that Kalepu et al. have proposed are reputation and availability [9]. Considering the designing attributes of the criteria for CloudEval based on user-specified QOS requirement for service level, and the objective and quantitative benchmarks, we add two attributes, response time (as speed of service from CloudHarmony) and financial credit from SLA. In this paper, we design seven main attributes: availability, response time, price, reputation (as user rating), network performance (as network latency), system performance (as performance), and financial credit. Furthermore, we extend the subattributes of the network performance attribute and the system performance attribute to include all the benchmark testing in CloudHarmony.

2.3. Grey System theory and Grey Relational Analysis

Grey System theory has been widely applied to handle information concerned the systems that do not have enough information or is unknown. Deng indicates that the aims of Grey System theory are to provide theory, techniques, notions and ideas for resolving (analyzing) latent and intricate systems. The Grey Relational Space (GRS) and Grey Generating Space (GGS) are the essential contents and topics of Grey System theory [10]. Based on GRS and GGS, In addition, Grey Relational Analysis (GRA) in Grey System theory has been widely applied to analyzing multivariate data for decision making [10, 11]. GRA ranks alternatives, represented as compared sequences, by their nearness to the ideal criteria, represented as a referenced sequence.

GRA reflects a form of fuzzification of inputs, and uses different calculations, to include different calculation of norms [12]. Thus, GRA uses Grey Relational Generation (GRG) method to map all the data into GRS by normalizing disorderly raw data. Sallehuddin et al. indicate that the raw data can be turned to a regular list for the benefit of grey modelling, transferred to a dimensionless list in order to obtain an appropriate fundamental for grey analyzing and changed into a unidirectional series for decision making [11]. GRA calculates a Grey Relational Coefficient (GRC) for each dimension (i.e. attribute), and then it calculates a grey relational grade by averaging all GRCs of each dimension for each compared sequence of the dimensionless list. Above all, GRA is simple, practical, and demands less precise information than other methods. Therefore, we adopt GRA method to select the optimal service which satisfies user-specified service level most.

3. THE CLOUD SERVICE SELECTION MODEL

The stakeholders of CloudEval are users, third-party brokers of cloud service and cloud service providers. The design of data sources for CloudEval is SLAs from providers and any trusted third-party brokers, such as CloudHarmony, which offers reputation of providers, some objective and quantitative benchmark-testing data. CloudEval consists of two components: selection process and data structure. We describe both components respectively as follows.

3.1. Selection Process

We apply the well-known multi-attribute decision making technique, Grey Relational Analysis, to our selection process. The service selection process is as follows.

1st step. Setting user selection criteria, goals and their weights: a user sets one's selection criteria of cloud service, acting as a referenced sequence in GRA, and sets weight and goal for each attribute. The goals are represented with preference for value of an attribute of the selection criteria.

2nd step. Normalizing the candidate list: we normalize each cloud service acting as a compared sequence of the candidate list in GRG method.

3rd step. Calculating Grey Relational Coefficient (GRC) of the attributes of each service: we use Deng's method [13] to calculate all GRCs of the attributes of each cloud service based on the comparison between each compared sequence and the referenced sequence.

4th step. Calculating grey relational grade for each service: we calculate a grey relational grade for each cloud service by averaging all the grey relational coefficient of each attribute. As for the way of averaging all the grey relational coefficient, we use both Deng's equal-weighted average method [13] and weighted average method.

5th step. Ranking the list: we rank the candidate list by ordering grey relational grade of each service. Finally, we choose the largest grey relational grade in the ranked list as the optimal service which satisfies user-specified service level most.

3.2. Data structure

Each cloud service of provider j is a compared sequence, $X[j] = (x_1, x_2, \dots, x_m) \in \text{Domain}(A_1) \times \dots \times \text{Domain}(A_i) \times \dots \times \text{Domain}(A_m)$, where $j = 1..n$. X[0] is a referenced sequence in GRA. Both X[0] and X[j] have a fixed-length vector with attribute-value pairs of a data instance, A_i is an attribute of X, $i = 1..m$. As mentioned in Section 2.2, we have designed the seven main attributes of selection criteria. The attributes availability, response time, network performance, system performance and financial credit are QOS-related and the attribute user rating and price are not QOS-related. As for the goals for each attribute of the selection criteria, the bigger the better are the attributes *availability*, *user rating*, *network performance*, *system performance* and *financial credit*; the less the better are the attributes *response time* and *price*. We design the attributes in detail as follows.

3.2.1. Availability

It is also known as the uptime status, the percentage of available connectivity time during a time period from a service provider. When a remote cloud service is usable as a user connects the service online, we call the time *connectivity time*; When a remote cloud service is unusable, it might be offline, under maintenance, shutdown, breakdown or instable as a user connects the service online. We call the time *connectivity downtime*. We define *availability* as:

$$availability = (connectivity\ Time - connectivity\ downtime)/connectivity\ time \quad (1)$$

3.2.2. Response Time

It is also called as round trip time or speed to represent the time duration between sending out a request and receiving a response to a service user. Its measured unit maybe second or millisecond.

3.2.3. User Rating

Some customers have rated each cloud service according to their usage experiences of the service on some broker websites. It is often rated from 0 to 5. A user refers to the rating as a social reputation.

3.2.4. Price

Due to budget limit, a user will consider the announced pricing published by a provider. The pricing is on a per-use basis, which maybe per minute, hour, day, or month, under different system environment configurations of instance type of a cloud service. The environment configurations could contains number of CPU cores, size of RAM and storage, network throughput, etc.

3.2.5. Network Performance

Suppose each benchmark item of network performance of a cloud service collected from a broker, *n[i, j]*, where *i* is the i-th benchmark item, and *j* is the j-th provider. The measured unit of each benchmark item is MBS (Mega-Bits per Second) for throughput. Due to metric of each benchmark item has different value range, we set the scale of the network performance from 0 to 1. Thus, we normalize each benchmark item as:

$$net[i,j] = (n[i,j] - min\_thput[i]) \,/\, (max\_thput[i] - min\_thput[i]) \quad (2)$$

where *max_thput[i]*: the maximum average summary network performance among all the i-th benchmark items of each provider, *min_thput[i]*: the minimum average summary network performance among all the i-th benchmark items of each provider. Then, we calculate the average summary network performance for the j-th provider by weighted average scoring as:

$$avg\_net\_scores[j] = \sum_{i=1}^{n} w[i] * net[i,j] \quad (3)$$

where *w[i]*: the user-specified weight of the i-th benchmark item.

3.2.6. System Performance

Suppose each benchmark item of system performance of a cloud service for a provider from a broker, *s[i, j]*, where *i* is the i-th benchmark item and *j* is the j-th provider. Due to metric of each benchmark item has different measured unit and value range, for instance, it is IOPS (Input/Output Operations Per Second) for disk IO; there are ECUs (EC2 Compute Unit) [3] or CCUs (CloudHarmony Compute Unit) [3] for CPU performances. We set the scale of all the system performances from 0 to 1. Thus, we normalize each benchmark item as:

$$sys[i, j] = (s[i, j] - min\ val[i]) / (max\ val[i] - min\ val[i]) \quad (4)$$

where *max_val[i]*: the maximum average summary system performance in all the i-th benchmark items of each provider, *min_val[i]*: the minimum average summary system performance in all the i-th benchmark item of each provider.

Then, we calculate the average summary system performance for the j-th provider by weighted average scoring as:

$$avg\_sys\_scores[j] = \sum_{i=1}^{n} w[i] * sys[i, j] \quad (5)$$

where *w[i]*: the user-specified weight of the i-th benchmark item.

3.2.7. Financial Credit

It means that percentage of monthly bill (i.e. credit rate) for covered a cloud service or service credit which does not meet the availability level in SLA from a provider that will be credited to future monthly bills of customer [14, 15]. Each credit rate is counted on an availability interval. As each interval of provider may be different from a similar user-specified interval, for example, the availability intervals, [99.00%, 99.95%) vs. [98.00%, 99.96%) are shown in Table 2(a) and Table 1 respectively. For comparability of both the credit rates in different availability intervals, we design an algorithm, adjust-interval-credit as shown in Figure 1, to adjust each pair of the original credit of a provider: ([99.00%, 99.95%), 10%) as shown in Table 2(a) into pair of the adjusted credit: ([98.00%, 99.96%), 17.65%) as shown in Table 2(b).

In the algorithm, suppose each interval of financial credit or service credit of a cloud service in SLA from a provider, *cred[k, j]*, where *k* is the k-th availability interval and *j* is the j-th provider. The measured unit of each interval is credit rate for a user-specified interval of monthly availability percentage. The scale of the credit is from 0 to 1. The descriptions of some important symbols of *cred[k, j]* are specified as: (1) length: the length of an interval; (2) upperBound: the upper bound of an interval; (3) lowerBound: the lower bound of an interval; (4) newUpperBound: the adjusted upper bound of an interval; (5) newlowerBound: the adjusted lower bound of an interval; (6) upperBound.Δ: a new interval between upperBound and newUpperBound; (7) lowerBound.Δ: a new interval between lowerBound and newLowerBound; (8) upperBound.Δ.rate: the rate of upperBound.Δ; (9) upperBound.Δ.length: the length of upperBound.Δ; (10) newLength: the new length of an adjusted interval; (11) middle.length: the adjusted interval between lowerBound.Δ and upperBound.Δ.

Table 1. A user-specified financial credit list.

Interval No.	Availability Interval (Monthly)	Credit Rate
1	[98.00%, 99.96%)	10%
2	[94.00%, 98.00%)	25%
3	[0, 94.00%)	50%

Table 2. The adjusted credit based on the original credit.

	Original Credit List (a)		Adjusted Credit List (b)	
Interval No.	**Availability Interval**	**Credit Rate**	**Availability Interval**	**Credit Rate**
1	[99.00%, 99.95%)	10%	[98.00%, 99.96%)	17.65%
2	[95.00%, 99.00%)	25%	[94.00%, 98.00%)	31.25%
3	[0, 95.00%)	50%	[0, 94.00%)	50.00%

Algorithm *adjust-interval-credit*(*j*, *n*, *user-credit-list, provider-credit-list*)

Input: j: the j-th provider; *n*: the number of user-specified availability intervals; *user-credit-list*: a list of each user-specified pair, (interval *k*, credit rate *c*); *provider-credit-list*: a list of each pair of a service, (interval *k*, credit rate *c*).

Output: an adjusted list of pair of a service, (interval *k*, credit rate *c*).

(1) initialize all the required variables;
(2) *cred[1, j].length* = *cred[1, j].upperBound* - *cred[1, j].lowerBound*;
(3) **For** each interval of *provider-credit-list* and *user-credit-list*, *k* = 1 to *n* **do loop**
(4) *cred[k+1, j].length* = *cred[k+1, j].upperBound* - *cred[k+1, j].lowerBound*;
(5) *cred[k, j].newUpperBound* = *user[k].upperBound*;
(6) **If** (*cred[k, j].upperBound* < *user[k].upperBound*) **Then**
cred[k,j].upperBound.Δ.*rate* = *cred[k, j].rate*;
cred[k, j].upperBound.Δ.length = *user[k].upperBound* - *cred[k, j].upperBound;*
cred[k, j].newLength = *cred[k, j].length* + *cred[k, j].upperBound*.Δ.length;
(7) *cred[k, j].newLowerBound* = *user[k].lowerBound*;
(8) **If** (*cred[k, j].lowerBound* > *user[k].lowerBound*) **Then**
cred[k, j].lowerBound.Δ.*rate* = *cred[k+1, j].rate*;
cred[k, j].lowerBound.Δ.length = *cred[k, j].lowerBound* - *user[k].lowerBound*;
cred[k, j].newLength = *cred[k, j].newLength* + *cred[k, j].lowerBound*.Δ.length;
(9) **If** (*cred[k, j].upperBound*.Δ.length < 0 and *cred[k, j].lowerBound*.Δ.length ≧ 0) **Then**
cred[k, j].middle.length = *cred[k, j].length* + *cred[k, j].upperBound*.Δ.length;
cred[k, j].newRate = (*cred[k, j].middle.length / cred[k, j].newLength*) * *cred[k, j].rate* +
(*cred[k, j].lowerBound*.Δ.length / *cred[k, j].newLength*) * *cred[k, j].lowerBound*.Δ.*rate*;
(10) **If** (*cred[k, j].upperBound*.Δ.length < 0 and *cred[k,j].lowerBound.rate*.Δ.length **< 0) Then**
cred[k, j].middle.length = *cred[k, j].length* + *cred[k, j].upperBound.rate*.Δ.length +
cred[k,j].lowerBound.rate.Δ.length;
cred[k, j].newRate = *cred[k, j].rate*;
(11) **If** (*cred[k, j].upperBound*.Δ.length ≧ 0 and *cred[k, j].lowerBound.rate*.Δ.length **< 0) Then**
cred[k, j].middle.length = *cred[k, j].length* + *cred[k, j].lowerBound.rate*.Δ.length;
cred[k, j].newRate = (*cred[k, j].upperBound*.Δ.length / *cred[k, j].newLength*) *
cred[k, j].upperBound.Δ.*rate* + (*cred[k, j]. middle.length /cred[k, j].newLength*) * *cred[k, j].rate*;
(12) **If** (*cred[k, j].upperBound*.Δ.length ≧ 0 and *cred[k, j].lowerBound.rate*.Δ.length ≧ 0) **Then**
cred[k, j].newRate = (*cred[k, j].upperBound*.Δ.length / *cred[k, j].newLength*) *
cred[k,j].upperBound.Δ.*rate* + (*cred[k, j].length / cred[k, j].newLength*) * *cred[k, j].rate* +
(*cred[k, j].lowerBound*.Δ.length / *cred[k, j].newLength*) * *cred[k, j].lowerBound*.Δ.*rate*;
(13) **End For Loop**
(14) return the list of each (*newLowerBound, newUpperBound*, *newRate*) of *cred[k, j]* of the service;

Figure 1. The *adjust-interval-credit* algorithm

After adjusting the intervals and credits of a service, we calculate the average credit rate for the j-th provider by weighted average method as:

$$avg\_credit\_scores[j] = \sum_{k=1}^{n} w[k] * cred[k,j] \tag{6}$$

, where *w[k]*: the user-specified weight of the k-th availability interval.

4. EXPERIMENTS

4.1. Design of experiments

We have conducted two groups of experiments. One group is for the comparison between CloudEval with adopting weighted attribute and human raters with adopting weighted attribute. The other group is for the comparison between CloudEval without adopting weighted attribute and human raters with adopting weighted attribute. The experimental steps have been conducted according to the process of CloudEval mentioned in Section 3.1. Besides, we have invited six raters to select by ranking the sample services manually. CloudEval used two toolboxes of GRG and GRC, mentioned in Section 2.3 and 3.1, written in MATLAB by [16]. Both the toolboxes were processed in MATLAB 7.0.1 for each experiment.

According to Table 3, we first generated a synthetic data set as shown in Table 4 with the seven attributes. All experiments use the dataset, in which were simulated as data from the broker, CloudHarmony, and SLA. The dataset is used as the input sample data for CloudEval and the raters in each experiment. The sample size of the data set is 30, numbered from X0 to X30. Service, X0, is the referenced sequence, whose values are the selection criteria of a cloud service; and all the services from X1 to X30 are the compared sequences, searched by CloudEval and the raters.

For evaluating the effectiveness of the experimental results, this study adopts the commonly used indicators, i.e. *Pearson correlation coefficient* (represented as ρ) and *Spearman's rank correlation coefficient* (represented as γ_s) to evaluate and compare the correlation between the rank lists of cloud services selected by the raters and by CloudEval. And, all the *correlation coefficients* were processed in PASW Statistics 18 (formerly SPSS Statistics) for each experiment.

Table 3. The attributes of experimental dataset.

Attributes	Value	Attributes	Value
Id (A0)	The identifier of the cloud services	*Price* (A4)	Randomly sampling data, normally distributed N(700, 350) from 1 cents to1,500 cents
Availability (A1)	Randomly sampling data, uniformly distributed from 0.9 to 1	*network performance* (A5)	Randomly sampling data, normally distributed N(3, 1.5) from 0 to 5
response time (A2)	Randomly sampling data, normally distributed N(15, 6) from 1 to 30 seconds	*system performance* (A6)	Randomly sampling normally distributed N(3.2, 0.8) from 0 to 5
user rating (A3)	Randomly sampling data, normally distributed N(3, 1) from 0 to 5, increased by 0.5.	*financial credit* (A7)	Randomly sampling data, normally distributed N(2.5, 1) from 0 to 5

Table 4. The experimental dataset.

	Main Attributes						
Cloud Service Id	**A1**	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**
X0	0.9500	15.0000	3	700	4.0000	4.0000	3.0000
X1	0.9806	13.5264	2.5	1000	2.8124	4.1928	3.1019
X2	0.9253	15.8717	2	900	3.2980	3.6547	3.5741
X3	0.9250	18.4351	2	600	2.8198	3.6701	4.3903
X4	0.9458	13.6599	4	1400	2.4443	4.2056	1.8874
X5	0.9081	9.7423	0	600	4.8067	3.0971	2.4509
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
X29	0.9109	18.2752	0.5	1000	4.0468	4.7359	2.9475
X30	0.9279	7.0281	5	300	1.9785	1.9483	2.5362

4.2. Experimental Results

The experimental results in Table 5 show that comparison of both the groups' correlation coefficients between the rank lists of cloud services selected by the raters and by CloudEval. As the sample size is 30, large enough, the values of both the correlation coefficients ρ and γ_s are the same values. Thus, we only illustrate *Spearman's rank correlation coefficient*, γ_s. At the significance level of $\alpha = 0.01$, all the experiments of γ_s in Table 5 illustrate that all the Bivariate Correlation tests are significantly different from zero in ρ between the rank-lists of user and CloudEval. It indicates that both groups of CloudEval are considerably correlative to the experimental results of the raters. As the average γ_s are increased from 0.6796 into 0.6952, it shows that CloudEval adopting weighted attribute can really improve both *Pearson correlation coefficients* and *Spearman's rank correlation coefficients* of CloudEval without adopting weighted attribute.

The experimental results in Table 6 show that each optimal service id, selected by user with adopting weighted attribute, by CloudEval without adopting weighted attribute, or by CloudEval with adopting weighted attribute. Both the groups of CloudEval have selected X9 as the optimal service. As for comparing with user's selection, three of the six raters have selected the same optimal service X9 as CloudEval have done; three of them have selected X26 or X27 as the optimal service. As the majority of the raters select the optimal services same as CloudEval, it shows that they are considerably correlative.

After all the discussion of the results above, therefore, we can say that CloudEval is effective, especially while the quantity of the candidate cloud services is much larger than human raters can handle.

Table 5. Comparison of both the groups' correlation coefficients.

	Cloud Service Selection Model	
	without weighted attribute	**with weighted attribute**
User ID	***Spearman's ρ coefficient***	***Spearman's ρ coefficient***
U1	0.7557**	0.7557**
U2	0.5205**	0.5272**
U3	0.6684**	0.6858**
U4	0.8700**	0.8752**
U5	0.6533**	0.6958**
U6	0.6093**	0.6315**
Average	**0.6796**	**0.6952**

**: p-value < 0.01.

Table 6. The optimal service ids selected by the experiments.

	The Optimal Service Id		
User ID	**by user with weighted attribute**	**by *CloudEval* without weighted attribute**	**by *CloudEval* with weighted attribute**
U1	X9	X9	X9
U2	X27	X9	X9
U3	X9	X9	X9
U4	X9	X9	X9
U5	X26	X9	X9
U6	X26	X9	X9

5. CONCLUSIONS

For solving the problem of discovering a user's optimal parameter portfolio for service level and evaluating the nonfunctional properties of any kind of candidate cloud services, we have proposed the cloud service selection model, CloudEval, to evaluate the nonfunctional properties and select the optimal service which satisfies both user-specified service level and goals most. And, CloudEval adopting weighted attribute can improve the correlation with a rater's selection of CloudEval without adopting weighted attribute.

The design of data sources for CloudEval is SLAs from providers and any trusted third-party broker, such as CloudHarmony, which offers user rating, some objective and quantitative benchmark-testing data. We recommend CloudEval which will easily offering applications for industrial users to select any cloud services through real data from a trusted third-party broker, as well as price and SLA data from cloud service providers. For future work, as users feel more comfortable to use fuzzy concept to weight among attributes, we will combine fuzzy technique with grey relational analyzing technique for the weighting. In additions, we also plan to adapt CloudEval more automatically for users to apply it over the Internet.

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PERFORMANCE EVALUATION OF A LAYERED WSN USING AODV AND MCF PROTOCOLS IN NS-2

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ABSTRACT

In layered networks, reliability is a major concern as link failures at lower layer will have a great impact on network reliability. Failure at a lower layer may lead to multiple failures at the upper layers which deteriorate the network performance. In this paper, the scenario of such a layered wireless sensor network is considered for Ad hoc On-Demand Distance Vector (AODV) and Multi Commodity Flow (MCF) routing protocols. MCF is developed using polynomial time approximation algorithms for the failure polynomial. Both protocols are compared in terms of different network parameters such as throughput, packet loss and end to end delay. It was shown that the network reliability is better when MCF protocol is used. It was also shown that maximizing the min cut of the layered network maximizes reliability in the terms of successful packet transmission of network. Thetwo routing protocolsare implemented in the scenario of discrete network event simulator NS-2.

KEYWORDS

AODV, MCF and NS-2.

1. INTRODUCTION

The advancements in wireless communication technologies enabled large scale wireless sensor networks (WSNs) deployment. As there is no fixed infrastructure between wireless sensor networks for communication, routing becomes an issue in large number of sensor nodes deployed along with other challenges of manufacturing, design and reliability of these networks [5-8].

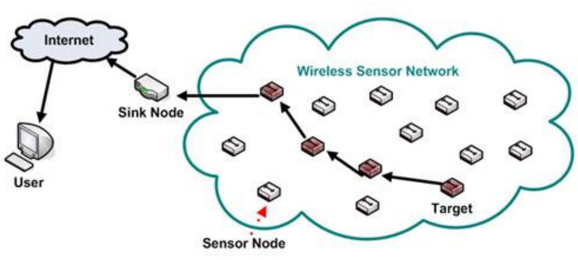

Figure 1: Wireless Sensor Network.

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The main issue of concern in this paper is Reliability. WSN network architecture is often layered. Reliability issues in layered networks may be often due to two reasons:

- Link failures: A link failure occurs when the connection between two devices (on specific interfaces) is down.

- Device failures: A device failure occurs when the device is not functioning for routing/forwarding traffic.

Lower layers generally experience random link failures. Each link failure at lower level may lead to multiple failures at the upper layers.There are many proposed concepts which tend to improve the reliability of any network. Modern communication networks are designed with one or more electronic layers (e.g.,IP, ATM, SONET) built on top of an optical fiber network. The survivability of such networks under fiber failures largely depends on how the logical electronic topology is embedded onto the physical fiber topology using lightpathrouting.However, assessing reliability performance achieved by a lightpath routing can be rather challenging because seemingly independent logical links can share the same physical link, which can lead to correlated failures. To avoid these kinds of failures, there are various routing protocols that have been proposed for routing data in wireless sensor networks. The mechanisms of routing consider the architecture and application requirements along with the characteristics of sensor nodes. One of the widely used protocols for data transmission in WSN is the following AODV routing protocol.

1.1 AODV Protocol

There are two types of routing protocols which are reactive and proactive. In reactive routing protocols, the routes are created only when source wants to send data to destination, whereas proactive routing protocols are table driven. Being a reactive routing protocol, AODV uses traditional routing tables, one entry per destination and sequence numbers are used to determine whether routing information is up-to-date and to prevent routing loops.

The maintenance of time-based states is an important feature of AODV which means that a routing entry which is not recently used is expired. The neighbors are notified in case of route breakage. The discovery of the route from source to destination is based on query and reply cycles and intermediate nodes store the route information in the form of route table entries along the route. Control messages used for the discovery and breakage of route are Route Request Message (RREQ), Route Reply Message (RREP), Route Error Message (RERR) and HELLO Messages.

When a source node does not have routing information about destination, the process of the discovery of the route starts for a node with which source wants to communicate. The process is initiated by broadcasting of RREQ. On receiving RREP message, the route is established. If multiple RREP messages with different routes are received then routing information is updated with RREP message of greater sequence number.

a) Setup of Reverse Path:

The reverse path to the node is noted by each node during the transmission of RREQ messages. The RREP message travels along this path after the destination node is found. The addresses of the neighbors from which the RREQ packets are received are recorded by each node.
b) Setup of Forward Path:

The reverse path is used to send RREP message back to the source but a forward path is setup during transmission of RREP message. This forward path can be called as reverse to the reverse path. The data transmission is started as soon as this forward path is setup. The locally buffered data packets waiting for transmission are transmitted in FIFO-queue.

The following example shows how data transmission takes place using AODV protocol:

- Node 1 sends RREQ to 2, 3, 4:
  "*Any one has a route to 15 fresher than 3. This is my broadcast #10*"
- Nodes 2, 3, 4 send RREQ to 5, 6, 7
- Node 3 has 3-5-8-9-10 Sequence #1
- Node 4 has 4-6-8-10 Sequence #4
- Node 4 responds. Node 3 does not respond.

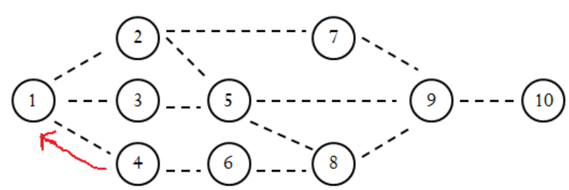

Figure 2: AODV Protocol

1.2 MCF protocol

The MCFlightpath routing algorithm MCFMinCut can be formulated as an integer linear program (ILP): MCFMinCut : Minimize ρ, subject to:ρ ≥X(s,t)∈EL w(s, t)fstij∀(i, j) ∈EPfstij∈ {0, 1}{(i, j) : fstij= 1} forms an (s, t)-path in GP , ∀(s, t) ∈EL,where w(s, t) is the weight assigned to logical link (s, t).

The optimal lightpath routing under this algorithm is determined by the weights w(s, t). For example, if w(s, t) is set to 1 for all logical links, the above formulation will minimize the number of logical links that traverse the same fiber. In other words, this uniform weight function treats each logical link equally, and seeks to minimize the impact of a single physical link failure on the number of disconnected logical links.

However, the connectivity is not well captured under this function since the logical network may remain connected even when a large number of logical links fail. In order to better account for the connectivity, the weight function w(s, t) = 1 /MinCutL(s,t) is used, where MinCutL(s, t) is the size of the min-cut between nodes s and t in the logical topology. Intuitively, this weight function attempts to minimize the impactof a single fiber failure to the logical connectivity, where impact is defined to be the total sum of weight of the logical links that traverse the fiber. Since the weight is defined to be 1/MinCutL(s,t) , a logical link that belongs to a small cut will contribute more weight than a logical link in a large cut.

2. PROPOSED IMPLEMENTATION

The above two protocols are implemented on a WSN network and the characteristics of the network in both cases, in terms of different network parameters, are compared. There are some network simulators that require commands or scripts while other simulators are GUI driven. In network simulation, the behavior of network models is extracted from information provided by network entities (packets, data links, and routers) by using some calculations. In order to assess the behavior of a network under different conditions different parameters of the simulator (environment) are modified.

Network Simulator (NS) is an object-oriented, discrete event driven network simulator that simulates a variety of IP networks, written in C++ and OTcl. It is primarily useful for simulating local and wide area networks. It implements network protocols such as TCP and UDP, traffic behavior such as FTP, Telnet, Web, CBR and VBR, router queue management mechanism such as Drop Tail, RED and CBR, routing algorithms such as Dijkstra, and more. NS also implements multicasting and some of the MAC layer protocols for LAN simulations. NS develops tools for simulation results display, analysis and converters that convert network topologies to NS formats.

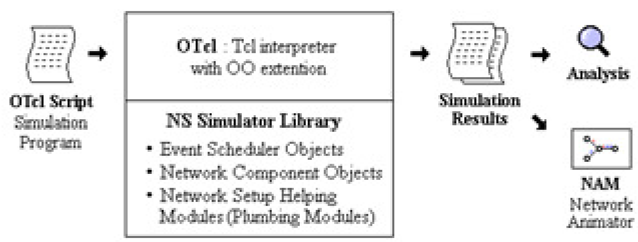

Figure 3: NS Simulator.

The generic script structure in NS-2 has the following steps: Create Simulator object, Turn on tracing, Create topology, Setup packet loss, link dynamics, Create routing agents, Create application and/or traffic sources, Post-processing procedures (i.e. nam), and Start simulation.

For designing any protocol in NS-2, the major steps to follow is define the following in Tcl scripts: Hello Packets, Timers used for Broadcast, Interval, Hello and Functions:

a) General for Packet Handling
b) Routing Table Management
c) Broadcast ID Management
d) Packet Transmission Management
e) Packet Reception Management

The flow of protocol in NS-2 is as follows. Let us consider AODV protocol for example.

1.In the TCL script, when the user configures AODV as a routing protocol by using the command,
$ns node-config –adhocRouting AODV
The pointer moves to the “start” and this “start” moves the pointer to the Command function of AODV protocol.

2. In the Command function, the user can find two timers in the “start”
* btimer.handle((Event*) 0);
* htimer.handle((Event*) 0);
3. Let’s consider the case of htimer, the flow points to HelloTimer::handle(Event*) function and the user can see the following lines:

```
agent ->sendHello();
double interval = MinHelloInterval + ((MaxHelloInterval - Min-
HelloInterval) * Random::uniform());
assert(interval ->= 0);
Scheduler::instance().schedule(this,      &intr,interval);
```

These lines are calling the sendHello() function by setting the appropriate interval of Hello Packets.

4. Now, the pointer is in AODV::sendHello() function and the user can see Scheduler::instance().schedule(target , p, 0.0) which will schedule the packets.

5. In the destination node AODV::recv(Packet*p, Handler*) is called, but actually this is done after the node is receiving a packet.

6. AODV::recv(Packet*p, Handler*) function then calls the recvAODV(p) function.

7. Hence, the flow goes to the AODV::recvAODV(Packet *p) function, which will check different packets types and call the respective function.

8. In this example, flow can go to case AODVTYPE HELLO:
recvHello(p);
break;

9. Finally, in the recvHello() function, the packet is received. The general trace format is shown in Figure 4

Every protocol generally uses some weight function for each link to traverse through the network. As we have seen above, AODV protocol uses sequence number to decide on the route which it should traverse. So, sequence number acts as weight in the protocol. In the same way, shortest path algorithm considers minimum number of hops as the weight. As we see by definition on MCF algorithm, it considers 1/MinCutL(s,t) as the weight function where MinCutL(s, t) is the size of the min-cut between nodes s and t in the logical topology.

According to the network topology, Mincut is the number nodes in a route which satisfies both the conditions of minimum number of hops and minimum weight of the route. Here, weight of the route is sum of weights of all the links in the route.

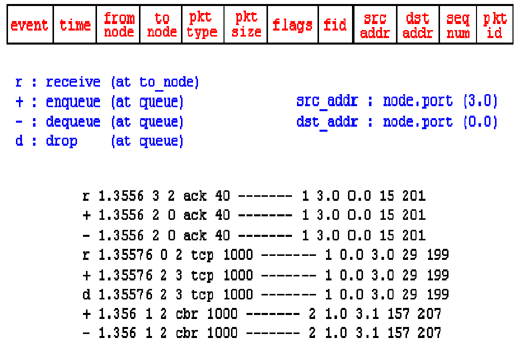

Figure 4: General Trace Format.

MCF algorithm greedily takes the path which has minimum weight and then checks for the condition of minimum number of hops. AODV is taken as the program and it is modified by adding the conditions for MCF algorithm.

3. SIMULATION RESULTS

Software Requirements:

Programming Language: TCL, C++, OTCL
Simulator: NS2 2.35
User Interface: NAM
Operating System Environment: Ubuntu 11.0

Hardware Requirement:

RAM: Min 1GB (Configuration)
Installation: 2GB RAM required
Hard Disk: 40GB
Processor: Minimum Configured with 2.0GHZ speed

Network Parameters:

- Network : WSN
- Number of Nodes : 80
- Routing Protocol : AODV/Lightpath
- Agent : TCP
- Application : CBR
- Communication range 250 unit
- MAC 802.11
- Traffic CBR, 8 Kbps per flow
- # of Flows 50
- Pause Time 5 second
- Max Speed 10 unit / s

In order to analyze statics report of proposed network model, various scenarios are evaluated for determining performance report of cross layer reliability model by employing various experiments. However, link failure always impact performance, the entire study has concerned with security with performance prospective. In any layered networks, link failure always consumes some energy. The main aim here is to compare the two protocols AODV and MCF by computing different scenarios for 80 nodes. Each node configured with defined layered network properties. In order to configure layered network, MAC layer properties and node properties are defined by adjusting parameters.

The next task is to select the routing protocol and define channels for configured network accordingly.

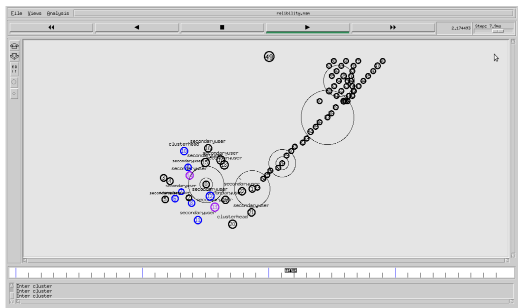

Figure 5: Simulated Network.

The designed network with four source nodes and 80 nodes is shown in Figure 5. After simulating the above network using the two protocols AODV and MCF, trace files are acquired. Then, the comparison is carried out for the two protocols with the help of performance parameters like end-to-end delay, throughput and Packet loss. By observing the results and graphs, the two protocols are analyzed in terms of reliability.

3.1 Throughput

Throughput is the ratio of the total amount of data that a receiver receives from a sender to a time it takes for receiver to get the last packet. The 80 nodes network is configured by assigning server and client nodes. Then, throughput is computed by analyzing server nodes and normal nodes transmission performance. Throughput is defined as the number of packets successfully processed per second. The average throughput rate increases with respect to total amount of packets generated. Figure 6 shows the throughput versus time of the 80 nodes network simulated using both AODV and MCF protocols. The network performance is analyzed in four different time intervals defined as there are 4 source nodes in the network. In each segment, number of packets successfully transmitted through special nodes and average rate of packets delivered in a different timelines are computed. In Figure 6, there is comparison between throughput performance of network using AODV and MCF at a scenario considering the performance of single source node.

The red line represents MCF protocol throughput and the yellow line corresponds to throughput due to AODV in units of bytes/sec. As it is seen from the figure, the simulation of first source node starts at 0.5 sec in both the scenarios. The throughput rate is very high here as Node 1 is the only transmitting node using the entire available bandwidth. This justifies the high performance of Node 1 during the specified interval of time. If we observe, at almost all the points of time, the red line has a higher throughput value compared to the yellow line. This shows that MCF has a better throughput performance.

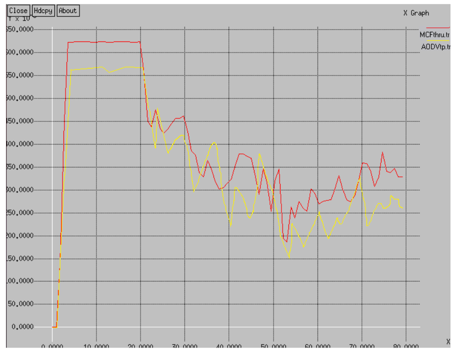

Figure 6: Throughput Comparison.

3.2 Packet Loss

At the physical layer of each wireless node, there is a receiving threshold. When a packet is received, if its signal power is below the receiving threshold, it is marked as error and dropped by the MAC layer.Packets Loss is defined as the total number of packets dropped during the simulation.

Lower the value of packet loss, better the performance of the protocol. In Figure 7, the red line represents AODV protocol and the blue line corresponds to MCF. The performance graph of a third source node which starts at 30 sec in both scenarios is considered. It is clear that packet loss with AODV protocol is higher than that of MCF protocol. At some points of time, packet loss due to AODV protocol is reaching very high peaks around 140 packets lost. The highest loss is around 100 packets in the case of MCF.

3.3 End to End Delay

The End to End delay is the average time taken by a data packet to arrive at the destination. It also includes the delay caused by route discovery process and the queue in data packet transmission. Only the data packets that successfully delivered to destinations are counted.

Average delay = ∑ (arrive time – send time)/∑ Number of connections. The lower value of end to end delay means the better performance of the protocol. The end-to-end delay over a path is the summation of delays experienced by all the hops along the path. In order to compute this metric over a wireless channel, each node needs to monitor the number of packets buffered at the network layer waiting for MAC layer service, as well as measuring the transmission failure probability at the MAC layer. The transmission failure probabilityis the probability that a MAC-layer transmission fails due to either collisions or bad channel quality. Figure 8 shows the end to end delay performance for the 80 nodes network.

The red line represents AODV protocol and the blue line corresponds to MCF. As shown from the figure, the performance graph of a third source node which starts at 30 sec is considered for both scenarios. It is clear that end to end delay of packets in the network with AODV protocol is higher than that of MCF. When AODV protocol is used, the peak delay of a packet reaches 700 μ sec where as it is around 550 μ sec in MCF.

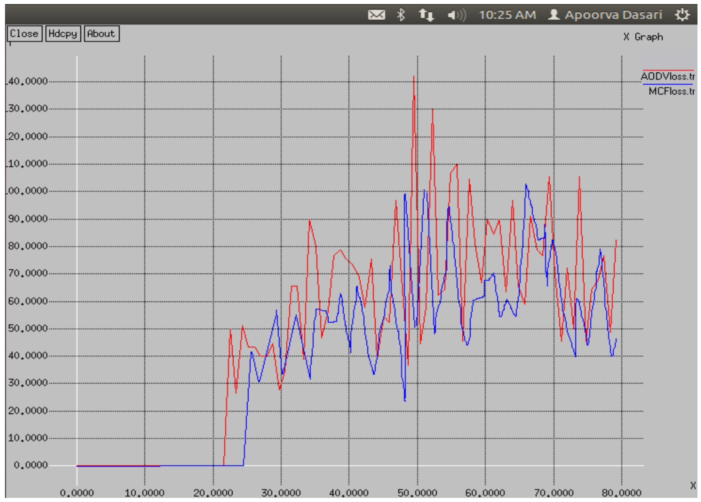

Figure 7: Packet Loss.

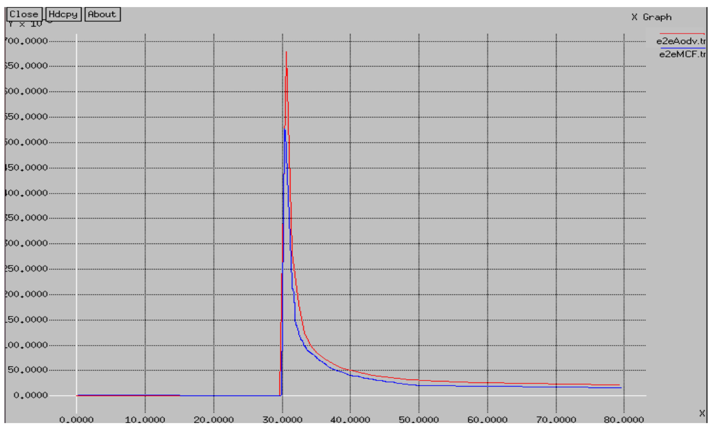

Figure 8: End to End delay.

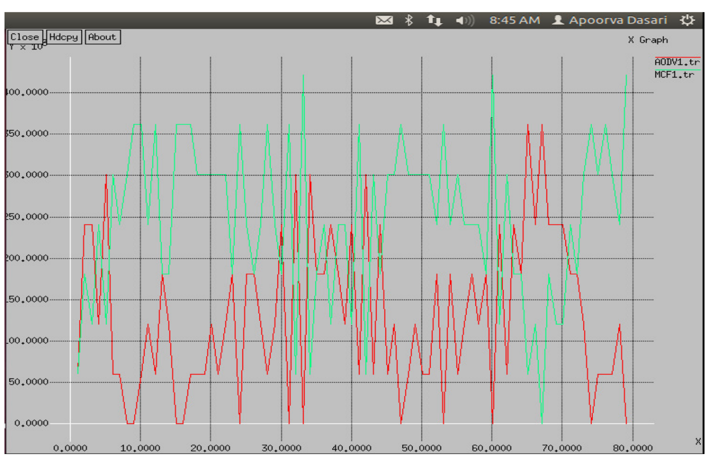

Figure 9: Successful Packet Transmission.

3.4 Successful Packet Transmission:

The trend of successful packet transmission is observed in both the protocols. Figure 9 shows the number of successfully transmitted packets during the simulation time. The green line represents packet transmission in MCF and red line in AODV protocols. At almost all points, MCF has higher successful transmission rate compared to AODV protocol.

4. CONCLUSION

In this paper, Wireless Sensor Network is implemented with AODV and MCF protocols. MCF uses mincut as weight function. Comparison of the performance of both the protocols in terms of different network parameters such throughput, packet loss and end to end delay is carried out. It is observed that in terms of all the network parameters, MCF protocol shows better performance compared to AODV protocol. The comparison in terms of successful packet transmission rate is also observed which showed that MCF protocol has better reliability compared to AODV. Therefore, a more reliable network with better performance can be designed using MCF protocol.

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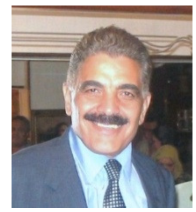

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