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DYNAMIC TIMETABLING USING REACTIVE CONSTRAINT AGENTS

HANY ALASHWAL^{1*} & SAFAAI DERIS²

Abstract. Most of the approaches that have been applied to solve the timetabling problems focus on the construction of the timetable as a static process. In real world, the timetabling problems are dynamic and open problems since the initial timetable is not fixed and it is required to be changed as the constraints or assumptions on which the timetable is based on, are changed or became invalid. Therefore, the main objective of this paper is to handle the changes after generating the initial timetable gradually by communicating and cooperating with each other to maintain the timetable feasibility. This architecture has been implemented and tested using real data from Faculty of Science, University of Ibb - Yemen. The results show that the RCA can cope with the changes in real-time with minimal modification to the existing timetable.

Keywords: Timetabling problem, dynamic timetabling, constraints programming, software agents, open agent architecture

Abstrak. Kebanyakan teknik yang diimplimentasi bagi menyelesaikan masalah penjadualan tertumpu kepada proses yang statik. Walau bagaimanapun, di dalam dunia sebenar, masalah penjadualan merupakan satu masalah yang terbuka, dinamik dan sentiasa berubah-ubah mengikut kekangan dan andaian. Oleh yang demikian, objektif utama kertas ini adalah untuk mengendalikan perubahan-perubahan yang berlaku setelah jadual waktu awalan terhasil. Agen Kekangan Reaktif (AKR) telah diimplimentasi lebih khusus dan berkeupayaan membaiki dan mengubahsuai jadual waktu secara bertahap dengan komunikasi dan kerjasama di antara satu sama lain bagi mengekalkan kesauran jadual waktu tersebut. Seni bina AKR ini telah dilaksana dan diuji dengan menggunakan data sebenar iaitu data dari Fakulti Sains, Universiti Ibb, Yemen. Hasil kajian menunjukkan bahawa AKR berupaya mengendalikan perubahan-perubahan dalam masa nyata dengan pembaikan yang minimum ke atas jadual waktu asal.

Kata kunci: Masalah penjadualan waktu, penjadualan waktu dinamik, pengaturcaraan terhad, agen perisian, seni bina agen terbuka

1.0 INTRODUCTION

The timetabling problems are combinatorial problems that consist of scheduling a set of courses within a given number of rooms and timeslots. Solving a real-world timetabling problem manually often requires a significant amount of time, sometimes

^{1&2} Faculty of Computer Science and Information Systems, Universiti Teknologi Malaysia, 81310 Skudai, Johor, Malaysia

Corresponding author: Tel: +607 5532541, Fax: +607 5565044, Email: hany@siswa.utm.my

several days or even weeks. It has been known that the timetabling problem fall under the NP-complete problems [1]. Moreover, it is a dynamic and perturbed problem. Constraints alter as unexpected events occur, such as adding or deleting resources which are subjects or lecturers, and as the changes of the user demands put on to the scheduling system.

During the last thirty years, many contributions related to the timetabling problem have appeared and it will probably continue with the same rate for years. This could be due to the fact that timetabling problems are often over-constrained, dynamic, and optimization criteria are hard to define. Different techniques have and are being applied to solve the static timetabling problem, including graph coloring [2], integer programming [3] (from Operations Research), simulated annealing [4], tabu search [5], genetic algorithms [6], and constraint logic programming [7] (from Artificial Intelligence). Most of the existing timetabling systems focus on the static part of the timetabling problem and generate a near optimal solution. Moreover, the required modification or changes are usually done manually, which is difficult and time consuming.

In the dynamic timetabling problem, the main task is to minimally reconfigure schedules in response to a changing resources or activities [8]. A survey of current approaches to dynamic scheduling in general can be found in [9]. Dynamic timetabling problem has started to be investigated in [10]. Another approach to cope with the changes after the first schedule has been generated is by using an interactive tool [11]. Using this method, user must interact with the system to modify the schedule during the rescheduling process.

Recently, software agents have been applied to cope with the dynamic scheduling problems [12-14]. Agent Technology has received a great deal of attention among the researchers and practitioners in the field of Artificial Intelligence (AI). These agents are typically reactive, treating the world as an external memory from which knowledge can be retrieved by perception. Furthermore, the AI community has shown an increasing interest in solving Constraints Satisfaction Problems using the agent technology [15]. Constraint computation provides a general problem-solving framework whereas agents are self-directed problem-solving entities [16].

2.0 DYNAMIC TIMETABLING PROBLEM

In order to manage a rapid growth of academic activities in a university, an efficient and flexible timetabling must be developed. Figure 1 shows a typical university timetabling processes. Timetabling is thus an ongoing and continuous process. The problem of updating timetables in the most effective way, when the constraints or assumption on which they are based are changed or became invalid, is one that is receiving increasing attention amongst researchers and practitioners.

The main alternatives to the revision of a timetable are either by completely rescheduling the original timetable from scratch, or by repairing or modifying the

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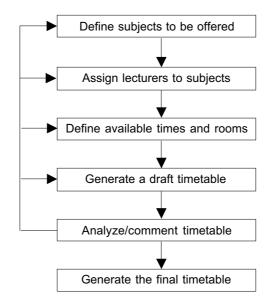


Figure 1 Timetable construction process

previous timetable interactively such as the approach that has been used by [11]. However, most approaches to reactive scheduling are based on infrequent regeneration which cannot maintain continuity as it is progressively modified. Therefore, the aim of this paper is to show how to cope with the dynamic timetabling problem by using Reactive Constraint Agents (RCA). Many cases can arise which is always leading to some modifications to the current timetable such as:

- (i) Turnover of academic staff.
 - (a) Adding teaching staff: This problem can occur when teaching staff has just finished a study leave or new staff has joined. It can also be considered as a free staff.
 - (b) Unplanned staff absences: This problem can occur due to retirement, illness, or emergence of other commitment of a teaching staff. It can also occur when a teaching staff gets a study leave.
- (ii) Dynamic of enrolments make section or subject unavailable or inadequate.
 - (a) Deleting sections or subjects. This problem occurs when there is not enough students to enroll in the subject. It can also be considered a free staff.
 - (b) Adding new sections or subjects that previously are not being offered. This problem occurs in case of extra students or a new subject has been offered.
 - (c) Adding/deleting activities (lectures, tutorials, seminars, etc.).

- (d) Amending lecturers (swapped from one lecture to another, dropped from/ added to lecturers).
- (e) Grouping teaching activities.

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(iii) Request for changing timetable: This problem may occur due to lecturers' preferences to move class to better fit their timetable and so forth.

As shown above, it is difficult to maintain a given timetable on a real timetabling problem because of all kinds of disturbances that occur as mentioned above. The manual solution for the dynamic timetabling problem is based on the try-check principle. This manual technique is a time-consuming process. In addition, there is no guarantee that the new timetable is a conflict-free solution. Meanwhile, most of the current timetabling systems are static in which the first near optimal timetable is generated automatically. Then, any new timetable required to be computed due to changes or new requirements will be done manually.

3.0 REACTIVE CONSTRAINT AGENTS ARCHITECTURE

The Reactive Constraint Agents (RCA) is a multi-agent architecture aimed to implement a reactive system that is capable of coping with the dynamic timetabling problem. In the RCA, each agent executes specific types of tasks, and serves a specific purpose. No agent does an entire job. Rather, it does what it can, then delegates the other tasks to other agents. The RCA uses the Open Agent Architecture (OAA^{TM}) [17] as a platform. The Open Agent Architecture is a blackboard-based framework allowing individual software agents to communicate by means of goals posted on a blackboard controlled by a facilitator. The facilitator is responsible both for storing data that is global to the agents, identifying agents that can achieve various goals, and scheduling and maintaining the flow of communication during the computation. An extension of Prolog is used as the Inter-agent Communication Language (ICL) to take advantage of unification and backtracking when posting queries. The primary job of the facilitator is to decompose ICL expressions and route them to agents who have indicated a capability in resolving them. Thus, agents can communicate in an undirected fashion, with the blackboard acting as a broker. In the timetabling system, many activities have to be done in order to construct a timetable that satisfies all constraints simultaneously and optimize the timeslots and room as much as possible. By analyzing the system, the roles are identified and each role is mapped to an agent type. The agent should be able to perform the tasks associated with its role. In the timetabling process, there are different roles:

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- (i) Lecturer
- (ii) Students' group

- (iii) Administrators
- (iv) Timetable designer

There are four basic domain agents that represent the described roles in the timetabling system. For these agents to do their tasks and communicate with each other, two other agents should be considered:

- (v) Facilitator
- (vi) Database agent

Figure 2 shows the architecture of the reactive constraint agents. This architecture consists of six types of agents:

- (i) Facilitator: The OAA facilitator is a specialized server agent that is responsible for coordinating agent communications. The facilitator is also used to provide a global data store for its client agents, which allows them to adopt a blackboard style of interaction.
- (ii) Administrator agent: This agent is created to represent the faculty administrator in the timetabling system. It has the authority to introduce a new change of the resources or the subjects in the timetabling system.
- (iii) Timetabler agent: This agent is responsible for repairing the timetable when it is necessary. It can cooperate with the database agent, lecturer agents and students' group agents to accomplish his task.
- (iv) Database agent: This is a special agent that establishes a connection with the timetabling database. It can provide the required data to the agent community.
- (v) Lecturer agents: This is a personal agent to represent the lecturers in the timetabling system. It stores the availability and the preferences of its user. This agent can ask the timetabler agent to change his timetable. If there are available timeslots and rooms, the timetabler agent can change and update the timetable of the corresponding lecturer.
- (vi) Students' group agents: This is a personal agent to represent the student groups in the timetabling system. It stores the availability and preferences of its user. This agent can ask the timetabler agent to change his timetable. If there is available timeslots-rooms and the related lecturer agent agree to change, the timetabler agent can change and update the timetable of the corresponding lesson.

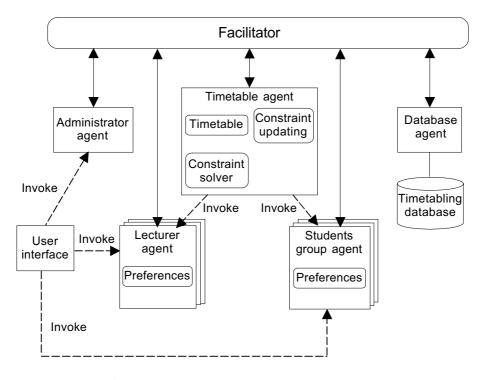


Figure 2 The reactive constraint agents architecture

4.0 AGENTS COMMUNICATION AND COORDINATION

Communication among agents takes place through the facilitator. It usually does this by providing two main services: routing outgoing messages to the appropriate destination and translating incoming messages for consumption by its agents. Cooperation among the agents in the RCA is achieved via messages expressed in a common language; ICL, and is normally structured around a three-part approach: providers of services register capabilities specifications with a facilitator, requesters of services construct goals and relay them to a facilitator, and facilitators coordinate the efforts of the appropriate service providers in satisfying these goals.

When a new change is introduced, negotiation and cooperation among agents is necessary to resolve the constraints violation and repairing the existing timetable. As unexpected events or requests occur, negotiation and cooperation between agents is necessary to resolve the constraints violation and repairing the modified timetable. The agents interact with each other to recognize and categorize the conflict then select and apply the appropriate action in such way that all the constraints remain satisfied.

In the static timetabling problem, the constraints processing is done before the generation of the timetable (i.e. it is done during the assigning process), however in the dynamic problem, the constraint must be processed based on the current timetable.

This constraints processing can be regarded as real-time constraints processing. In order to handle the new events or the requested changes, the RCA uses algorithms that maintain the constraints in real time manner. In this problem, the variables are the timeslot $T(S_i)$ and the room $R(S_i)$ for each lesson S_i . The values to be assigned to timeslot variables $T(S_i)$ are the total available timeslots in a week, t_j , $1 \le j \le m$. The values assigned to a room variable $R(S_i)$ are the available rooms rk, $1 \le k \le p$, where p is the number of the available rooms.

A solution to a timetabling problem can be defined as assignment of time tj, $1 \le j \le m$ and room rk, $1 \le k \le p$ to lessons S_i , $1 \le i \le n$ taught be lecturer $L(S_i)$ such that all constraints $C(S_i)$ are satisfied. $L(S_i)$ and $C(S_i)$ are lecturers and constraints of lesson S_i , respectively.

The constraints referred to the relationship between two variables. The basic constraints or relations are the mathematical relations, i.e., \leq , \geq , = and \neq . The types of constraints that have to be satisfied in the timetabling process at Ibb University are as follows:

(i) Lecturer time-clash constraints: A lecturer cannot teach more than one subject in the same timeslot.

$$T(S_i) \neq T(S_j)$$
 if $L(S_i) = L(S_j)$ (1)

where $T(S_i)$ and $T(S_j)$ are the timeslots for the subject S_i and S_j respectively. $L(S_i)$ and $L(S_j)$ are the lecturers of the subjects S_i and S_j respectively, i, j = 1, 2, ..., n

(ii) Group time-clash constraints: A students group cannot attend more than one subject at the same timeslot.

$$T(S_i) \neq T(S_i)$$
 if $G(S_i) = G(S_i)$ (2)

where $G(S_i)$ and $G(S_j)$ are the students groups of the subjects S_i and S_j respectively, i, j = 1, 2, ..., n

(iii) Room time-clash constraints: Not more than one subject can be assigned to one room at the same timeslots.

$$T(S_i) \neq T(S_j)$$
 if $R(S_i) = R(S_j)$ (3)

where $R(S_i) = R(S_j)$ are the classrooms of the subjects S_i and S_j respectively, i, j = 1, 2, ..., n

(iv) Room capacity constraints: The number of students for subject assigned to the room must be less or equal to the capacity of the room.

$$N(S_i) \le Z(R(S_i)) \tag{4}$$

where $N(S_i)$ is the number of students of the subject S_i and Z(R) is the capacity of the room R, i, j = 1, 2, ..., n

Before making any change, we must make sure that this change will not lead to violate any constraints. Therefore, we should check the lecturer time-clash constraints, group time-clash constraint, room time-clash constraint and room capacity constraint during the rescheduling process. The timetabler agent uses Get_Available algorithm (Figure 3) to find all the available timeslots and rooms for a specific lesson. Indeed to find the available timeslots and rooms, we must ensure that the change will not lead to violate any constraints.

```
Algorithm Get Available
Input : timetable [n,3] : array of int //the first column represents the lesson
                                      id
                                    //the second column represents the
                                      timeslot
                                    //the third column represents the room
                                      id
                                    //n is the number of lessons
    subject[n] : array of subject_record
               : array of room_record //p is the number of rooms
    room[p]
    lessonId
               : int
    no_of_timeslots: int
    continue
              : boolean
Output : list_free_tm_rm
Begin
  k := 1
  continue := true
  While k < = n And continue Do
    If subject[k].lesson = lesson Then
        continue = false;
    Else k = k + 1
    EndIf
  EndWhile
  lecturer id = subject[k].lecturer
  group id = subject[k].group
  no students = subject[k].no students
  For timeslot = 1 To no of timeslots Do
    If is lecturer free(t, lecturerID) And is group free(t, groupID) Then
        For room = 1 To p Do
            If is_room_free(t,r) And room_capacity(r) >= no_Students Then
              list free tm rm.Add(timeslot,room)
            EndIf
        EndFor
    EndIf
  EndFor
End
```



()

5.0 RESULTS AND DISCUSSION

To validate the results, it is essential to implement a system prototype of the proposed architecture to verify its properties. The prototype implementation is tested by modeling the timetabling problem at University of Ibb - Yemen. In this system prototype, the initial timetable was generated using the hybrid genetic algorithm which has been introduced in [18]. The timetabling problem at University of Ibb - Yemen has been modeled as a constraints satisfaction problem then solved using the hybrid genetic algorithm. The basic information in the timetable planning data is shown in Table 1. There are 129 subjects, 226 lessons and 16 rooms of various capacities. There are 18 timeslots (6 days a week with 3 timeslots per day of 3 hours per lesson).

Items	Values
No. of subjects	129
No. of lessons	226
No. of teachers	41
No. of rooms	16
No. of timeslots	18

Table 1Basic information of timetable planning data

The near-optimal timetable which was generated using the hybrid genetic algorithm is used as an initial timetable for the dynamic timetabling system (Figure 4). See Appendix A for the full timetable that includes all timeslots.

		Saturday		1	Sunday	Mo			
					ounuay				
	8:00am - 11:00am	11:00am - 2:00pm	2:00pm - 5:00pm	8:00am - 11:00am	11:00am - 2:00pm	2:00pm - 5:00pm	8:00am - 11:00am	11:00am	
Room1 - 5	175 - BA42211 - 4AP Ahmed Talal - 4	116 - BP31261 - 3PS Adnan Almaitami - 6	118 - BP33101 - 3PS Ahmed Al-yahya - 5	125 - BP42101 - 4PS Ahmed Al-yahya - 5	51 - BM35031 - 3PS Zain Al-eragi - 5		121 - BP35101 - 3PS Ahmed Al-yahya - 5	122 · BP382 Mohd Abdel	
Room2 - 10	180 - BF32231 - 3F Riad Mohamed - 10	172 - BA35221 - 3AP Abbas Hussain - 8	47 - BM32312 - 4F Abbas al-eragi - 10	85 - BC36122 - 3F Mohd Anozaily - 10	170 - BA33141 - 3AP Sabah Ahmed - 8	169 - BA32251 - 3AP Mohamed Shaker - 8	179 - BF31111 - 3F Salma Hussain - 10	68 - BM4433 Moneer Ash	
Room3 - 15	183 - BF42141 - 4F Sabah Ahmed - 10	194 - BG42391 - 40 Ahmed Saif - 10	83 - BC34091 - 3CS Nasser Alkhatib - 13	39 - BM26402 - 2PS Adel Al-ofairy - 13	87 - BC37081 - 3CS Roshdy Modawer - 13	185 - BF44111 - 4F Salma Hussain - 10	197 - BG45211 - 40 Ahmed Talal - 10	80 - BC3108 Mohamed H	
Room4 - 25	106 - BA24191 - 2A Mohamed Raad - 20	163 - BA21411 - 2A Yahya Mohamed - 20	105 - BP21012 - 2PS Mohamed Sami - 13	92 - BC45081 - 4CS Mohamed Hashem - 17	190 - BG34341 - 36 Ahmed Fat-hee - 12			110 - BP220 Mohamed S	
Room5 - 70	38 - BM24032 - 3M Zain Al-eragi - 46	17 - BM13035 - 1M(S2) Zain Al-eragi - 63	13 - BM12402 - 1MS(S2) Adel Al-ofairy - 65	14 - BM13035 - 1MS(S1) Zain Al-eragi - 62	2 - BM11294 - 1MS(S2) Saba Alwan - 65		24 - BM14367 - 1MS(S2) Rashad Albaadani - 66		
Room6 - 75	43 - BM31151 - 2MS Hussain Ahmed - 61	20 - BM14357 - 1PS Rashad Albaadani - 53	35 - BM24032 - 2MS Zain Al-eragi - 61		6 - BM12284 - 2M Foad Hussain - 41	48 - BM32312 - 4M Abbas al-eragi - 49	37 - BM25361 - 2MS Fahd Abdussalam - 61	5 - BM12284 Foad Hussai	
Room7 - 75	73 - BC23063 - 2B Roshdy Modawer - 41	44 - BM31151 - 3M Hussain Ahmed - 45	74 - BC23063 - 1A Roshdy Modawer - 60	32 - BM22042 - 2MS Riad Ashehaid - 61		89 - BC42091 - 4C Nasser Alkhatib - 56	63 - BC12124 - 1B(S1) Mohd Anozaily - 70	15 - BM1303 Zain Al-erag	
Room8 - 75	108 - BP21012 - 4M Mohamed Sami - 49	82 - BC33091 - 3C Nasser Alkhatib - 56		80 - BC11091 - 1D Nasser Alkhatib - 50	40 - BM27042 - 2MS Riad Ashehaid - 61	161 - BB34171 - 3B Faisal Ali - 43	89 - BC22061 - 3C Roshdy Modawer - 56	64 - BC1212 Mohd Anoza	
Room9 - 75	150 - 8833181 - 48 Mohamed Badran - 26	111 - BP22011 - 2P Mohamed Sami - 30	144 - BB27181 - 2B Mohamed Badran - 41	112 - BP22011 - 3M Mohamed Sami - 45	81 - BC32021 - 31 Abdusalam Aljawfi - 30	218 - BS12276 - 1MS(S2 Adel Assodagi - 65	77 - BC24081 - 2CS Mohamed Hashem - 39	07 · BC2100	
Room10 - 75	206 - BS11387 - 1CS Ali Abdullah - 28	136 - BB14312 - 1B(S2) Abbas al-eragi - 71	167 - BA25191 - 2A Mohamed Raad - 20	138 - BB22161 - 2I Hady Mohamed - 52	107 - BP21012 - 1P(S2) Mohamed Sami - 70		132 - BB13191 - 1CS Mohamed Raad - 29	93 - BP1107 Khalaf Aliab	
Room11 - 75	214 - BS12278 - 1MS(S1 Adel Assodagi - 62	148 - BB32171 - 31 Faisal Ali - 30		141 - 8825191 - 28 Mohamed Raad - 41	143 - BB26171 - 2B Faisal Ali - 41		156 - BB38172 - 3B Faisal Ali - 43	115 - BP232 Adnan Alma	
Room12 - 120	95 - BP11075 - 11 Khalaf Aliabori - 87	68 - BC21061 - 2C Roshdy Modawer - 100		72 - BC23063 - 2C Roshdy Mod <i>a</i> wer - 10D	78 - BC24081 - 2C Mohamed Hashem - 100	205 - BS11387 - 11 Ali Abdullah - 87	71 - BC22091 - 2C Nasser Alkhatib - 100	139 - BB230 Mohamed F	
Room13 - 120	223 - BS13133 - 1B(S1) Ali Albamady - 70	104 - BP12071 - 1C Khalaf Aljabori - 120		213 - BS12276 - 1PS Mohd Almansory - 53	96 - BP11075 - 1C Khalaf Aljabori - 120		134 - BB14312 - 1I Abbas al-eragi - 87	142 - BB251 Mohamed R	
Room14 - 140		160 - BB43181 - 4B Mohamed Badran - 26			145 - BB27181 - 1A Mohamed Badran - 60		182 - BA12391 - 1A Ahmed Saif - 60	155 - BB3B1 Faisal Ali	
Room15 - 150		202 - BS11387 - 1A Ali Abdullah - 60					207 - BS11387 - 1C Ali Abdullah - 120	158 - BB411 Mohamed B	
Room16 - 170		211 - BS12276 - 1M(S1) Mohd Almansory - 62					221 - BS12278 - 1B(S2) Mohd Almansory - 71	181 - BF331 Salma Hussi	
	4				•	•			
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Figure 4 The initial near-optimal timetable

For the system prototype implementation, we use Java programming language, and for the database, we use Microsoft Access. As an example, we trace the scenario of deleting a classroom which leads to reschedule all the lessons that are assigned to this classroom. The following is an example of an operational demonstration scenario that illustrates inter-agent communication (Figure 5).

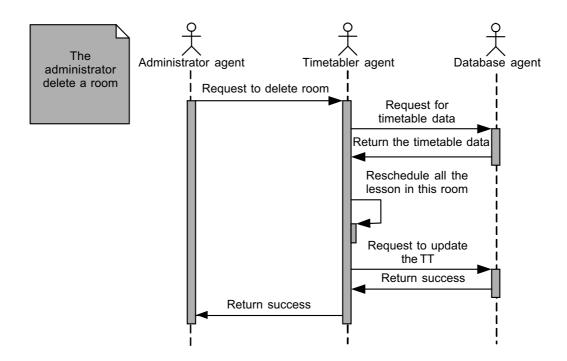


Figure 5 Example of agent interaction

When the administrator agent send a request for deleting a classroom, the timetabler agent receive this request and try to satisfy it. In order to handle this request, the timetabler agent need to cooperate with the database agent to get the sufficient timetabling data. After the timetabler agent gets the sufficient timetabling data, it applies appropriate action to reschedule all the lessons that were assigned in the deleted room. The new timetable is feasible and has minor changes from the initial timetable (see Figure 6). See Appendix A for the full new timetable that includes all timeslots. It also shows the difference between the initial timetable and the new timetable after deleting Room 16. For different scenarios that lead to changing timetable, see [19].

Unlike the previous interactive approach to cope with the dynamic timetabling problem that has been reported in [11], the use of reactive constraints agents which is introduced in this research, relieve human user from the responsibility of interfacing, task planning, and execution monitoring. This has several benefits,

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		Saturday			Sunday	Mor		
	8:00am - 11:00am	11:00am - 2:00pm	2:00pm - 5:00pm	8:00am - 11:00am	11:00am - 2:00pm	2:00pm - 5:00pm	8:00am - 11:00am	11:00am -
om1 - 5	175 - BA42211 - 4AP	116 - BP31261 - 3PS	118 - BP33101 - 3PS	125 - BP42101 - 4PS	51 - BM35031 - 3PS		121 - BP35101 - 3PS	122 - BP3620
00m2 - 10	Ahmed Talal - 4 180 - BF32231 - 3F	Adnan Almaitami - 5 172 - BA35221 - 3AP		Ahmed Al-yahya - 5 85 - BC36122 - 3F	Zain Al-eraqi - 5 170 - BA33141 - 3AP	169 · BA32251 · 3AP	Ahmed Al-yahya - 5 179 - BF31111 - 3F	Mohd Abdelk. 58 - BM4433
00m3 - 15	Riad Mohamed - 10 183 - BF42141 - 4F	Abbas Hussain - 8 194 - BG42391 - 4G			Sabah Ahmed + 8 87 + BC37061 + 3CS	Mohamed Shaker - 8 185 - BF44111 - 4F	Salma Hussain - 10 197 - BG45211 - 4G	Moneer Ashai 80 - BC31081
00m4 - 25	Sabah Ahmed - 10 166 - BA24191 - 2A	Ahmed Saif - 10 163 - BA21411 - 2A	Nasser Alkhatib - 13 105 - BP21012 - 2PS	Adel Al-ofainy - 13 92 - BC45081 - 4CS	Roshdy Modawer - 13 190 - BG34341 - 3G	Salma Hussain + 10	Ahmed Talal - 10	Mohamed Ha 110 - BP2201
	Mohamed Raad - 20 36 - BM24032 - 3M	Yahya Mohamed - 20 17 - BM13035 - 1M(S2)	Mohamed Sami - 13 13 - BM12402 - 1MS(S2)	Mohamed Hashem - 17 14 - BM13035 - 1MS(S1)		3 - BM11294 - 1M(S1)	24 - BM14357 - 1MS(S2	Mohamed Sa 4 - BM11294 -
oom5 - 70	Zain Al-eraqi - 45 43 - BM31151 - 2MS	Zain Al-eragi - 63 20 - BM14357 - 1PS	Adel Al-ofainy - 65	Zain Al-eragi - 62	Saba Alwan - 65	Saba Alwan - 62	Rashad Albaadani - 65 37 - BM25361 - 2MS	
00m6 - 75	Hussain Ahmed - 61 73 - BC23063 - 2B		Zain Al-eraqi - 61 74 - BC23063 - 1A	Rashad Albaadani - 62	Foad Hussain - 41	Abbas al-eraqi - 49	Fahd Abdussalam - 61	Foad Hussain
oom7 - 75	Roshdy Modawer - 41	Hussain Ahmed - 45	Roshdy Modawer - 60	Riad Ashehaid - 61	Rashad Albaadani - 63	Nasser Alkhatib - 56	83 - BC12124 - 1B(S1) Mohd Anozaily - 70	15 - BM13036 Zain Al-eragi
oom8 - 75	108 - BP21012 - 4M Mohamed Sami - 49	82 - BC33091 - 3C Nasser Alkhatib - 56		60 - BC11091 - 1D Nasser Alkhatib - 50		151 - BB34171 - 3B Faisal Ali - 43	69 - BC22061 - 3C Roshdy Modawer - 56	64 - BC12124 Mohd Anozai
oom9 - 75	150 - BB33181 - 4B Mohamed Badran - 26	111 - BP22011 - 2P Mohamed Sami - 30	144 - BB27181 - 2B Mohamed Badran - 41	112 - BP22011 - 3M Mohamed Sami - 45	81 - BC32021 - 3I Abdusalam Aljawfi - 30 ⊿	218 - BS12276 - 1MS(S2 Adel Assodagi - 65	77 - BC24081 - 2CS Mohamed Hashem - 39	67 - BC21061 Roshdy Moda
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oom11 - 75	214 - BS12276 - 1MS(S1 Adel Assodagi - 62		225 - BS13133 - 2CS Ali Alhamady - 39	141 - BB25191 - 2B Mohamed Raad - 41	143 - BB26171 - 2B Faisal Ali - 41		156 - BB38172 - 3B Faisal Ali - 43	115 - BP2326 Adnan Almaii
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Figure 6 The timetable after deleting Room 16

including reducing the complexity for users and agents, precipitating a more open and dynamically extensible computing style, and encouraging reuse across applications and domains.

Recently, [10] have used constraint-programming-based tools for solving dynamic timetabling problems modelled as resource-constrained project scheduling problems. Comparing this approach with the agent technology approach, the reactive constraint agents' architecture provides these advantages:

- (i) Flexibility of the system.
- (ii) Extensibility of the architecture, making it particularly easy to add and enhance agents.
- (iii) Modularity in which each agent is independent which eases development and maintenance.
- (iv) Ease of integration with other systems through the encapsulation of existing problem-solving systems as agents.
- (v) Reusability of the agents across multiple domains (e.g. utilizing existing agents in different scheduling systems).

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(vi) Adaptable to distributed environment.

Task	Agent	Time
Get available timeslots and rooms	Timetabler agent	8 seconds
Reschedule all lessons in a room	Timetabler agent	56 seconds
Add lesson	Timetabler agent	6 seconds
Provide the timetable data	Database agent	5 seconds
Update the timetable data	Database agent	2 seconds

Table 2The processing time for agents' tasks

The time performance of the system is shown in Table 2 which shows that the agents can react to the events in the timetabling system in a real time manner. In contrast, the manual modification of the initial timetable may take several days or even weeks.

In addition to the advantages of using agents' technology to handle the dynamic timetabling problem, the proposed reactive constraint agents' architecture can be applied to other dynamic problems, like dynamic manufacturing scheduling problem, meeting scheduling problem, and staff scheduling problem, with minor modification. This is due to the modularity of the agents and the flexibility of the system.

6.0 CONCLUSION AND FUTURE WORK

In this paper, we have presented a reactive constraint agents architecture that is capable of coping with the dynamic timetabling problem. The architecture has been implemented and a prototype has been produced. The implementation has been tested using real data from University of Ibb - Yemen. The experiments show that when a change is required to be done on the existing timetable, the timetabler agent can cooperate with other agents in the system to modify the timetable in such a way that all the constraints are satisfied simultaneously. Future work is needed to fully test all type of changes that can occur in the timetabling environment. Furthermore, the architecture can be implemented in a distributed environment.

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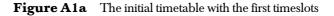
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APPENDIX A

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Figure A1b The new timetable with the first timeslots

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000m9 - / 5 Mohamed Hashem - 39 Bothy Modawer - 39 All Abdullah - 71 Sabah Amed - 50 Nasser Akkratib - 39 Adel Assodagi - 50 Mohamed Badran - 70 Nasser Akkratib - 39 Adel Assodagi - 50 Mohamed Badran - 70 Nasser Akkratib - 39 Adel Assodagi - 50 Mohamed Badran - 70 Nasser Akkratib - 39 Adel Assodagi - 50 Mohamed Badran - 70 Nasser Akkratib - 39 Adel Assodagi - 50 Mohamed Badran - 70 Nasser Akkratib - 39 Adel Assodagi - 50 Mohamed Badran - 70 Nasser Akkratib - 39 Adel Assodagi - 71 Mohamed Badran - 70 Nasser Akkratib - 39 Adel Assodagi - 71 Mohamed Badra - 71	oom8 - 75	3								61 - BC Roshdy	
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oom1 2 : 120 Nasser Alkhatib : 100 Mohame d Fahril : 52 Hady Mohamed - 41 All Khalest : 12 Abba 000m1 3 : 120 134. B614312 : 11 142. B625 (191 : 2A 146. B622 (171 : 21) 106. B044411 : 40 106. 000m1 3 : 120 134. B614312 : 11 142. B625 (191 : 2A 146. B622 (171 : 21) 106. B044411 : 40 106. 000m1 4 : 140 162. BA12391 : 1A 165. B638172 : 31 165. B632321 : 2A 206. B511587 : 116(51) 206. B511587 : 116(51) 210. B51271 : 61 All Abduilah : 62 Al	oom11 - 75		Faisal Ali - 43	Adnan Almaitami - 41	2		Mohamed Sami - 29		Ahmed Fat-hee - 60	137 - B Sabah	
oom13:120 Abbas al-eragi: 87 Mohamed Raad: 20 Faisal Ali: -52 Yahya Mohamed - 10 Moha oom14:140 162: BA12391 - 1A 165: BB2231 - 2A 206: B311387 - 116(51) 210: B312276 - 12 201: B3122	oom12 - 120		Nasser Alkhatib + 100	Mohamed Fakhri - 52			Hady Mohamed - 41		Ali Khaleel + 12	28 - BN Abbas .	
Dom'l 4 : 140 Anned Sair - 60 Faital Ali : 30 Riad Mohamed - 20 Ali Abdullah - 62 Ali Ab Dom'l 5 - 150 207 - BS 11387 - 11C 156 - BB41181 - 4B 199 - BS 11387 - 11C (\$1) 210 - BS 12276 - 1C 220 Dom'l 5 - 150 Ali Abdullah - 120 Mohamed Badran - 26 Ali Abdullah - 70 Adel Associary - 120 Mohamed Badran - 26 Ali Abdullah - 70 Adel Associary - 120 Mohamed Badran - 26 Ali Abdullah - 70 Adel Associary - 120 Mohamed Badran - 26 Ali Abdullah - 70 Adel Associary - 120 Mohamed Badran - 26 Ali Abdullah - 70 Adel Associary - 120 Mohamed Badran - 26 Ali Abdullah - 70 Adel Associary - 120 Mohamed Badran - 26 Ali Abdullah - 120 Mohamasory - 70 Adel Associary - 120 Mohamasory - 70 Adel Associary - 120 Mohamasory - 87 Ali Abdullah - 120 Mohamasory - 87 Ali Abdullah - 120 Ali Abdullah - 120 Adel Associary -	oom13 - 120		Abbas al-eragi - 87	Mohamed Raad - 20			Faisal Ali - 52		Yahya Mohamed - 10	153 - В Моћап	
000715-15U Ali Abdullah - 120 Mohamed Badran - 26 Ali Abdullah - 70 Adel Associagi - 120 Moho 00716 - 170 221 - B512276 - 18(52) 181 - BF33111 - 3F 222 - B512276 - 11 225 - B512276 - 11 225 - B512276 - 11 226 - B512276 - 11 227 - B512276 - 11 226 - B512276 - 11 227 - B512276 - 11 226 - B512276 - 11 227 - B512276 - 11 227 - B512276 - 11 226 - B512276 - 11 227 - B512276 - 11 226 - B512276 - 11 226 - B512276 - 11 227 - B5122	oom14 - 140		Ahmed Saif - 60	Faisal Ali + 30			Riad Mohamed - 20		Ali Abdullah + 62	Ali Abd	
000m16-17/U Mohd Almansony - 71 Salma Hussain - 10 Ali Al	oom15 - 150		Ali Abdullah - 120	Mohamed Badran - 26			Ali Abdullah - 70		and the second sec	220 - B Mohd A	
	oom16 - 170									225 - B Ali Alh	
		4								•	

Figure A2a The initial timetable with the middle timeslots

		Monday		Tuesday			Wednesday		
	0am	11:00am - 2:00pm	2:00pm - 5:00pm	8:00am - 11:00am	11:00am - 2:00pm	2:00pm - 5:00pm	8:00am - 11:00am	11:00am - 2:00pm	2:0
loom1 - 5	:PS - 6	122 - BP36202 - 3PS Mohd Abdelkarem - 5	176 - BA43221 - 4AP Abbas Hussain - 4	38 · BM26402 · 3PS Adel Al-ofairy - 5	178 - BA45221 - 4AP Abbas Hussain - 4		123 - BP36202 - 4PS Mohd Abdelkarem - 5	177 • BA44221 • 4AP Abbas Hussain • 4	128 - Moha
200m2 - 10	F	58 - BM44331 - 4MS	54 - BM41151 - 4MS	55 · BM42311 · 4MS	171 - BA34251 - 3AP Mohamed Shaker - 8	59 - BM45331 - 4MS Moneer Ashamiry - 9	188 - BF45231 - 4F Riad Mohamed - 10	198 - BG46341 - 40 Ahmed Fat-hee - 10	57 - B Mone
toom3 - 15	10 4G	Moneer Ashamiry - 9 80 - BC31081 - 3CS	Hussain Ahmed - 9 31 - BM21032 - 2PS	Abbas al-eraqi - 9 168 - BA31221 - 3AP	191 - BG35341 - 3G	184 · BF43221 · 4F	113 - BP23261 - 2PS Adnan Almaitami - 13	189 - B033211 - 30 Abmed Talal - 12	192 · Abme
200m4 - 25	<u>)</u>	110 - BP22011 - 2PS	Zain Al-eraqi - 13 173 - BA41251 - 4F	Abbas Hussain - 8 187 - BG31301 - 36	Ahmed Fathee • 12 88 - 8041081 - 405	45 - BM32312 - 3MS	62 · BM36361 · 3MS Fahd Abdussalam · 23	49 - BM34331 - 3MS Moneer Ashamiry - 23	48 - B Adnar
200m5 - 78		Mohamed Sami - 13 4 - BM11294 - 1M(S2)	1 - BM11294 - 1MS(S1)	to . bin none w (any	8 - BM12284 - 1PS	Abbas al-eragi - 23 12 - BM12402 - 1MS(S1) Adel Al-ofairy - 62		16 - BM13035 - 1M(S1) Zain Al-eragi - 62	10 - B Mohd
toom6 - 75	WS	Saba Alwan - 83 5 - BM12284 - 2P		Zain Al-eraqi - 70 23 - BM14357 - 1MS(S1) Rashad Albaadani - 62		94 · BP11075 · 2CS	2411 90-61401 - 70 34 - BM23311 - 2CS Abbas al-etadi - 39	22 - BM14357 - 1P(S2) Rashad Albaadani - 70	30 - B Zain A
toom7 - 75	- 61 3(S1) 70	Foad Hussain - 30 15 - BM13035 - 1MS(S2) Zain Al-eragi - 85		76 - BC23063 - 3C Roshdy Modawer - 56	29 - BM21032 - 2M Zain Al-eragi - 41	159 · 8842051 - 48	91 - BC44061 - 4CS Roshdy Modawer - 17	41 - BM27042 - 3M Biad Ashehaid - 46	97 - B Khala
toom8 - 75	20 2 - 56	84 - BC12124 - 1PS Mohd Anozaily - 53	193 - BG41321 - 4G	114 - BP23261 - 2P Adnan Almaitami - 30	86 - BC12124 - 1B(S2) Mohd Anozaily - 71	209 · BS11387 - 1M(82)		81 - BC12082 - 1CS Roshdy Modawer - 29	157 · Faisal
toom9 - 75	S	87 - BC21061 - 2CS Roshdy Modawer - 39		129 - 9812141 - 10 Sabah Ahmed - 50	70 - BC22091 - 2CS Nasser Alkhatib - 39	217 · BS12276 - 1D	131 - BB13181 - 1B(S1)		164 - Ahme
toom10 - 75	n - 39 CS 29	93 - BP11075 - 1CS Khalaf Aliabori - 29	226 - BS21271 - 2MS Adel Associati - 61	162 - 8836241 - 38 Abdulbaset Mohd - 49	117 - BP32071 - 3P Khalaf Aliabori - 58	211 - 8512270 - 1M(81) Mohd Almansory - 62		109 - BP21012 - 4C Mohamed Sami - 58	204 - Ali At
Room11 - 75	:B	Adnan Almaitami - 41	Adel Associati - o t		124 - BP41011 - 4P Mohamed Sami - 29		181 - BA11341 - 1A Ahmed Fathee - 60	137 - BB21141 - 21 Sabah Ahmed - 52	219 - Mohd
000m12-120	2	139 - 8823051 - 21 Mohamed Fakhri - 52		Aller Association - 70	140 - BB24161 - 2B Hady Mohamed - 41	181 - BF33111 - 3F Salma Hussain - 10	188 - 8632321 - 36 Ali Khaleel - 12	28 - BM15311 - 1C Abbas al-eragi - 120	
Room13 - 120	1	142 - 8825191 - 2A Mohamed Raad - 20			146 - 8928171 - 21 Faisal Ali - 52	The second se	198 - BG44411 - 4G Yahya Mohamed - 10	153 - BB36051 - 31 Mohamed Fakhri - 30	
Room14 - 140	A	155 - 9839172 - 31 Faisal Ali - 30	C	222 - BS12276 - 11 Mohd Almansory - 87	965 - BA23231 - 2A Phad Mohamed - 20		208 - 8511387 - 1M(51) Ali Abdullah - 62	201 - BS11387 - 1D Ali Abdullah - 50	
loom15 - 150	C	158 - 8841181 - 48			199 - BS11387 - 1B(S1)		210 - 8812276 - 1C 4 del fondogi - 100	220 - BS12278 - 1B(S1) Mobd Almonitor, 79	
00m16 - 170									
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Figure A2b The new timetable with the middle timeslots

			Wednesday Thursday			T he second second		
	esday			vvednesday			Inursday	
	n - 2:00pm	2:00pm - 5:00pm	8:00am - 11:00am	11:00am - 2:00pm	2:00pm - 5:00pm	8:00am - 11:00am	11:00am - 2:00pm	2:00pm - 5:00pm
Room1 - 5	221 - 4AP ain - 4		123 - BP36202 - 4PS Mohd Abdelkarem - 5	177 - BA44221 - 4AP Abbas Hussain - 4	126 - BP43011 - 4PS Mohamed Sami - 5	174 - BA41251 - 4AP Mohamed Shaker - 4	120 - BP34071 - 3PS Khalaf Aljabori - 5	127 - BP44011 - 4PS Mohamed Sami - 5
toom2 - 10	251 - 3AP Shaker - 8	59 - BM45331 - 4MS Moneer Ashamiry - 9	186 - BF45231 - 4F Riad Mohamed - 10	198 - BG46341 - 4G Ahmed Fat-hee - 10		53 - BM36361 - 4MS Fahd Abdussalam → 9	195 - BG43321 - 4G Ali Khaleel - 10	182 - BF41391 - 4F Ahmed Saif - 10
Room3 - 15	341 · 36 ·hee · 12	184 - BF43221 - 4F Abbas Hussain - 10	113 - BP23261 - 2PS Adnan Almaitami - 13	189 - B033211 - 30 Ahmed Talal - 12		84 - BC35091 - 3CS Nasser Alkhatib - 13	7 - BM12284 - 3CS Foad Hussain - 13	
Room4 - 25	81 - 4CS Hashem - 17	45 - BM32312 - 3MS Abbas al·eragi - 23	52 - BM36361 - 3MS Fahd Abdussalam - 23	49 - BM34331 - 3MS Moneer Ashaminy - 23		56 - BM43331 - 3MS Moneer Ashamiry - 23	79 - BC25111 - 2A Salma Hussain - 20	50 - BM35031 - 3MS Zain Al-eragi - 23
Room5 - 70	:4 - 1PS in - 53	12 - BM12402 - 1MS(S1) Adel Al-ofainy - 62	18 - BM13035 - 1P(S1) Zain Al-eragi - 70	16 - BM13035 - 1M(S1) Zain Al-eragi - 62		9 - BM12302 - 2B Mohd Mahmoud - 41	101 - BP11262 - 1M(S2) Adnan Almaitami - 63	11 - BM12302 - 1A Mohd Mahmoud - 60
Room6 - 75	:11 - 1CS aqi - 29	94 - BP11075 - 2CS Khalaf Aljabori - 39	34 - BM23311 - 2CS Abbas al·eraqi - 39	22 - BM14357 - 1P(S2) Rashad Albaadani - 70		21 - BM14357 - 1P(S1) Rashad Albaadani - 70	106 - BP21012 - 1P(S1) Mohamed Sami - 70	75 - BC23063 - 2CS Roshdy Modawer - 39
Room7 - 75	132 - 2M qi - 41	159 - BB42051 - 4B Mohamed Fakhri - 26	91 - BC44061 - 4CS Roshdy Modawer - 17	41 - BM27042 - 3M Riad Ashehaid - 45		33 - BM22042 - 3M Riad Ashehaid - 45	128 - BB11051 - 1D Mohamed Fakhri - 50	99 - BP11075 - 1MS(S2 Khalaf Aljabori - 65
loom8 - 75	24 - 18(S2) aily - 71	209 - BS11387 - 1M(S2) Ali Abdullah - 63	98 - BP11075 - 1MS(S1) Khalaf Aljabori - 62	61 - BC12062 - 1CS Roshdy Modawer - 29		42 - BM28031 - 2MS Zain Al-eragi - 61	203 - BS11387 - 1MS(S1 Ali Abdullah - 62	212 - BS12276 - 1M(S2) Mohd Almansory - 63
toom9 - 75	91 - 2CS atib - 39	217 - BS12276 - 1D Adel Assodagi - 50	131 - BB13181 - 1B(S1) Mohamed Badran - 70	90 - BC43091 - 4CS Nasser Alkhatib - 17		86 - BC36122 - 2I Mohd Anozaily - 52	216 - BS12276 - 1P(S2) Adel Assodagi - 70	
toom10 - 75	071 - 3P bori - 56		133 - BB13191 - 1B(S2) Mohamed Raad - 71	109 - BP21012 - 4C Mohamed Sami - 56	204 - BS11387 - 1MS(S2 Ali Abdullah - 65		224 - BS13133 - 1B(S2) Ali Alhamady - 71	
oom11 - 75	011 - 4P Sami - 29		161 - BA11341 - 1A Ahmed Fat-hee - 60	137 - BB21141 - 21 Sabah Ahmed - 52		119 - BP33101 - 4P Ahmed Al-yahya - 29	~	
toom12 - 120	161 - 2B med - 41		188 - BG32321 - 3G Ali Khaleel - 12	28 - BM15311 - 1C Abbas al-eraqi - 120		62 - BC12062 - 1C Roshdy Modawer - 120		65 - BC12124 - 1I Mohd Anozaily - 87
toom13 - 120	171 · 21 52		196 - BG44411 - 4G Yahya Mohamed - 10	153 - BB36051 - 31 Mohamed Fakhri - 30		130 - BB13161 - 1I Hady Mohamed - 87		
loom14 - 140	231 · 2A med · 20		208 - BS11387 - 1M(S1) Ali Abdullah - 62	201 - BS11387 - 1D Ali Abdullah - 50		135 - BB14312 - 1B(S1) Abbas al-eraqi - 70		
toom15 - 150	387 · 1B(S1) h · 70		210 - BS12276 - 1C Adel Assodaqi - 120	220 - BS12276 - 1B(S1) Mohd Almansory - 70		149 - BB33181 - 3B Mohamed Badran - 43		
Room16 - 170	276 · 11 Insory · 87			225 - BS13133 - 2CS Ali Alhamady - 39		154 - BB37051 - 3I Mohamed Fakhri - 30		
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			ectCode - GroupCode		 []	Calculate Score	Exit	1

Figure A3a The initial timetable with the last timeslots

	esday			Wednesday			Thursday	
	1 - 2:00pm	2:00pm - 5:00pm	8:00am - 11:00am	11:00am - 2:00pm	2:00pm - 5:00pm	8:00am - 11:00am	11:00am - 2:00pm	2:00pm - 5:00pm
oom1 - 5	221 - 4AP ain - 4		123 - BP36202 - 4PS Mohd Abdelkarem - 5	177 - BA44221 - 4AP Abbas Hussain - 4	126 - BP43011 - 4PS Mohamed Sami - 5	174 - BA41251 - 4AP Mohamed Shaker - 4	120 - BP34071 - 3PS Khalaf Aljabori - 5	127 - BP44011 - 4PS Mohamed Sami - 5
oom2 - 10	251 - 3AP Shaker - 8	59 - BM45331 - 4MS Moneer Ashamiry - 9	186 - BF45231 - 4F Riad Mohamed - 10	198 - BG46341 - 4G Ahmed Fat-hee - 10	57 · BM43331 · 4MS	53 - BM 36361 - 4M S Fahd Abdussalam - 9	195 - BG43321 - 4G Ali Khaleel - 10	182 - BF41391 - 4F Ahmed Saif - 10
oom3 - 15	341 - 36 -hee - 12	184 - BF43221 - 4F Abbas Hussain - 10	113 - BP23261 - 2PS Adnan Almaitami - 13	189 - BG33211 - 3G Ahmed Talal - 12	192 - BG36391 - 3G Ahmed Saif - 12	84 - BC35091 - 3CS Nasser Alkhatib - 13	7 - BM12284 - 3CS Foad Hussain - 13	
oom4 - 25	81 - 4CS Hashem - 17	45 - BM32312 - 3MS Abbas al-eragi - 23	52 - BM36361 - 3MS Fahd Abdussalam - 23	49 - BM34331 - 3MS Moneer Ashaminy - 23		56 - BM43331 - 3MS Moneer Ashamiry - 23	79 - BC25111 - 2A Salma Hussain - 20	50 - BM35031 - 3MS Zain Al-eragi - 23
oom5 - 70	14 - 1PS in - 53	12 - BM12402 - 1MS(S1) Adel Al-ofairy - 62			10 - BM12302 - 2I Mohd Mahmoud - 52	9 - BM12302 - 2B Mohd Mahmoud - 41	101 - BP11262 - 1M(S2) Adnan Almaitami - 63	11 - BM12302 - 1A Mohd Mahmoud - 60
oom6 - 75	:11 - 1CS aqi - 29	94 - BP11075 - 2CS Khalaf Aljabori - 39	34 - BM23311 - 2CS Abbas al-eraqi - 39			21 - BM14357 - 1P(S1) Rashad Albaadani - 70	106 - BP21012 - 1P(S1) Mohamed Sami - 70	75 - BC23063 - 2CS Roshdy Modawer - 39
oom7 - 75	132 - 2M gi - 41	159 - 8842051 - 48 Mohamed Fakhri - 26	91 - BC44061 - 4CS Roshdy Modawer - 17	41 - BM27042 - 3M Riad Ashehaid - 45	Khalaf Aljabori - 60	33 - BM22042 - 3M Riad Ashehaid - 45	128 - BB11051 - 1D Mohamed Fakhri - 50	99 - BP11075 - 1MS(S2 Khalaf Aljabori - 65
oom8 - 75	24 - 18(S2) aily - 71	Ali Abdullah - 63	98 - BP11075 - 1MS(S1) Khalaf Aljabori - 62	Roshdy Modawer - 29	Faisal Ali - 26	42 - BM28031 - 2MS Zain Al-eraqi - 61	203 - BS11387 - 1MS(S1 Ali Abdullah - 62	Monu Almansory 63
oom9 - 75	91 - 2CS atib - 39	217 - BS12276 - 1D Adel resonage - 50	Mohamed Badran · 70	90 - BC43091 - 4CS Nasser Alkhatib - 17	Ahmed Talal - 20	Mohd Anozaily - 52	216 - BS12276 - 1P(S Adel Assodagi - 70	154 - BB37051 - 31 Mohamed Fakhri - 30
oom10 - 75	071 - 3P bori - 56	211 - BS12276 - 1M(S) Mohd Almansory - 62	Mohamed Raad - 71	109 - BP21012 - 4C Mohamed Sami - 56	204 - BS11387 - 1MS(S2 Ali Abdullah - 65	Adnan Almaitami - 70	224 - BS13133 - 1B(S2) Ali Alhamady - 71	
oom11 - 75	011 - 4P Sami - 29	\geq	161 - BA11341 - 1A Ahmed Fat-hee - 60	137 - BB21141 - 2I Sabah Ahmed - 52	Mohd Almansory - 29	119 - BP33101 - 4P Ahmed Al-yahya - 29		
oom12 - 120	161 - 2B med - 41	181 - BF33111 - 3F Salma Hussain - 10	188 - BG32321 - 3G Ali Khaleel - 12	28 - BM15311 - 1C Abbas al-eragi - 120		62 - BC12062 - 1C Roshdy Modawer - 120		85 - BC12124 - 1I Mohd Anozaily - 87
oom13 - 120	171 - 21 52		196 - BG44411 - 4G Yahya Mohamed - 10	153 - BB36051 - 31 Mohamed Fakhri - 30		130 - BB13161 - 1I Hady Mohamed - 87		
oom14 - 140	231 - 2A med - 20		208 - BS11387 - 1M(S1) Ali Abdullah - 62 210 - BS12276 - 1C	Ali Abdullah - 50		135 - BB14312 - 1B(S1) Abbas al-eragi - 70 149 - BB33181 - 3B		
oom15 - 150	387 - 1B(S1)		210 - 8512276 - 10 Adel Associaçi - 120	220 - BS12276 - 1B(S1)		Nohamed Badian - 40		
oom16 - 170								
	4							[·

 $\label{eq:Figure A3b} \quad \text{The new timetable with the last timeslots}$

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