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Proposed Method to Allocate the Blood Units by Using a Hybrid of Real-Time Algorithms on the Cloud Environment

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Abstract: Blood units are a sensitive, scarce, and important resource in the health care system, which must be allocated to beneficiaries accurately, quickly, and efficiently. In this paper, we will propose a new method to allocate the blood units, which will be the major part of an integrated real-time system on a cloud environment, backed by smart device applications. The proposed method will use a hybrid of real-time algorithms some of supply chain principles, to develop the allocating operation of blood units to address the problems associated with the use of current traditional methods to allocate blood units. Where, the current methods in their works heavily rely on human intervention, paper documents, and traditional supply chain algorithms. Also, current methods suffer from many problems, including the potential for human error and dependence on the local scale to supply blood units most of the time, in addition to a high rate of miss allocation of blood units, especially for critical cases, And this is what we are working to overcome in the proposed method, to improve the performance of the allocation of blood units, and this, in turn, will improve the health care services provided to the beneficiaries. This proposed method will be applied to allocating blood units within the health care system of Nineveh Governorate.

Keywords: Real-Time Systems, Cloud Computing, Healthcare System, Blood Units Allocating

1. INTRODUCTION

Most of the traditional health care systems like the health care system in Mosul city (Nineveh Governorate, Iraq) contain a number of blood banks, donation centers, and blood allocation centers that operate independently of each other. Where, the process of communication between blood banks and with donation camps, donors, and patients depends on individual efforts [1]. This traditional health care systems use old method for allocating blood units depends on direct allocation and delivery using the first-in-first-out (FIFO) algorithm, and this algorithm despite it was ease and speed in allocating blood units, but it needs to have a safe level of reserve storage for blood units to keep the level of direct allocation of blood units within the required level [2]. Moreover, this method often suffers from the emergence of cases of shortages in the required blood units, especially for critical cases due to the allocation of these units to cases less important [1]. The current method addresses the problem of compensating for the shortage of blood units through traditional donation campaigns or asking the beneficiaries to provide donors with blood units, and this process even though it addresses the problem of deficiency of blood units in the quantity, but it does not solve the problem of deficiency of a specific type of blood units [3].

The most important reason for adopting the current method of allocating blood units on the algorithm of FIFO and within the local scale is the reliance of the current systems on human intervention and paper documents to a large extent [4]. The current method relies on human intervention in making decisions for allocating blood units, in addition to making decisions that change the level of safe storage and determine the blood type corresponding to the required and organizing documents. This causes a great slowdown in the process with the potential for human error [5]. Some of these obstacles were solved by converting documents from paper to digital using database applications, but this did not reduce the problem as required because the current method still depends on human intervention and local scope in its work, in addition to the high cost and the high health care staff effort it need [6].

Therefore, the need to propose a new method for allocating blood units based on modern technologies has

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become an urgent matter [7] [8]. This is to overcome the problems and obstacles of the current methods in addition to taking advantage of the capabilities and characteristics provided by modern technologies [9]. So, in this paper, we propose a new method for allocating blood units by relying on hybrid Real-time algorithms that will operate within the cloud environment, which will eliminate the need for human intervention in decision-making processes. The new method will make the allocation process more efficient, accurate, and transparent. The new method will be included within a proposed integrated central system for managing blood units, where this system will increase the efficiency of blood unit management operations while reducing the required cost.

The use of real-time algorithms in the allocation of blood units is the most important thing that distinguishes the new method from the rest of the methods and systems used previously and currently [10]. Real-time algorithms focus on creating the logically correct results and responses in a timely manner, and this is what will contribute greatly to the process of decision making to allocate blood units. Usually, the time constraints used to distinguish a non-real-time system from real-time systems, such as deadlines. Real-time systems can be classified depending on the deadline effect into Hard, Soft, and Firm real-time systems [11]. In Hard real-time systems, results must be reached within deadline otherwise the system will fail. These systems are essential to safety, and here, missing a deadline can have dire consequences. For example, managing critical emergencies in the healthcare system and the robot system, where a response is required within a deadline to avoid system failure [12]. In Soft real-time systems, the deadlines are final but not critical. If the system fails to meet the deadline, the system will not fail, but its performance will start to deteriorate. For example, the scheduling blood unit's allocation for non-critical surgeries. Here we are not saying system failure but we consider that the system is not working properly. In the Firm real-time system, here the system has a deadline and needs to achieve results in deadlines, but if you fall behind the deadline, the system won't fail but the late results will be worthless [13].

Also, tasks and events in real-time can be classified according to the way in which they occur over a period of time into Aperiodic, Periodic, and Sporadic tasks. Aperiodic task, it is a task that has no restrictions on known arrival times. For example, allocate blood units to emergency patients. In a periodic task, the task is repeated after a specific period of time known as the task period. For example, blood requests for thalassemia patients. In the Sporadic task, the task is repeated at random moments, which is non-cyclical, but with minimal internal time. These tasks can vary from somewhat critical to very critical tasks. For example, DMA interrupt and providing blood units for scheduled surgeries [14].

Cloud computing is used to offering the virtual environment, which has four main categories namely Public cloud, Private Cloud, Hybrid Cloud, and Community Cloud [15]. In Public Cloud, the cloud infrastructures are owned and managed by cloud providers usually organizations that provide cloud services, here the service provider offers the services publicly on the internet to the customers by the pay-as-you-use model [16]. Private Clouds are particularly allowing services to be accessible for a single enterprise only, the organization itself will provide and managed services. As it is private, it is more secured than a Public Cloud [17]. The Hybrid cloud is the combination of both Public Cloud as well as Private Cloud [18]. A Community Cloud is a model in which cloud infrastructure is shared, distribute, and manage between several numerous organizations. That is shared among several organizations or the group of people [19]. Also, Cloud computing offer numerous services types which include Software as a Service (SaaS), security as a Service (SecaaS), Infrastructure as a Service (IaaS), Platform as a Service (PaaS), and Database as a Service (DBaaS). Here we will rely on the services provided by the public cloud to provide the environment for the proposed new method, which will be at a lower cost and easier to access [20] [21].

2. Related Work

In this section, we will focus on approaches proposed in the literature that has focused on developing the functioning of health care systems and, in particular, developing blood unit management processes. Where, it focused in its entirety on the use of modern technologies, to improve the methods currently used in terms of raising the level of performance and reducing costs and facilitating communication, access, and use.

Authors [22] , they have been found that there is no authorized system for donation in the blood banks, which can make this donation easier, fast, and updated. And hospital still using excel sheets in computers and they contact people by a phone call or SMS in emergency cases. They discussed in this the possibilities of implementing a full network for hospital with cloud computing and mobile applications that can be a joint connection between the hospital and donor. This mobile application can be downloaded from the APP store by anyone and there will be website for peoples using computer. It will work as a coordinator between the central blood bank and donors in all the country.

Authors [23], focus on the problem when blood is required in a hospital, and often it cannot be provided in time this causes unpleasant things. Sometimes the donor is available to the hospital, but the patient does not know this, and neither does the donor. To solve this problem, communication must be established between the hospital, receptor, donor, and blood bank. There will be an Android application to make to speed up the work. It aims to generate information about the donor and the organization related to blood donation. The methodology used to build this system is to use a cloud computing and GPS system.

Authors [24] developed an integrated framework for all relevant and isolated online subsystems for the blood management system by using the cloud services. They propose a data warehouse (DW) as part of the integrated framework a central database for storing historical blood donation data for analytical processing. In this paper they presented a new standard for mankind is a system of scoring points for good deeds for citizens called Philanthropy Score (PS), the proposed system will enable the agencies responsible for the system Healthcare from making a blood donation camp based on analytical reports from DW. Also, the declared PS points for the citizen will be an additional incentive to donate blood

Authors [25] studied the radical changes that have been caused by the use of smart devices such as smartphones and tablets in many aspects, especially health services. The paper shows that the widespread use of smart devices can reduce doctor stresses, reduce health care costs, and speed the provision of patient care, and easy access to patient medical information. Therefore, the use of smart devices and information technology will not replace health personnel, but help them to provide better patient care. By providing health information electronically anywhere, anytime required, smart devices and health information technology applications can contribute to improving health quality and reduce costs.

Author [26], studied the effects of the increasing use on a wide range of smart devices equipped with high-resolution digital cameras and electronic visual touch screens and sensors, such as a laptop, smartphones, and tablets. That enabled software developers to use new ways to create applications that work in real-time disease surveillance and early warning. The research aims to identify convergence opportunities in the medical field through smart device applications that have been enabled by technological developments. And by using the methods and techniques of cloud environment platforms through which they can provide patient data in real time to doctors in remote locations.

3. PROPOSED SYSTEM

As we mentioned before, the new method will be included within a proposed integrated central system for managing blood units. The proposed system will be responsible for organizing and managing all operations related to blood units, including the allocation of blood units in the health care system as a whole [27]. Where, the proposed system will include all blood banks and blood donation camps within the health care system. The proposed system building structure contains three main models which are Cloud Environments, Android Application, and Support and backup systems.

A. Cloud Environments

In this component, we used the PaaS and SaaS services offers by the Microsoft Azure cloud [28]. This component includes the main management server, the main data store, authentication operation, and the status web page [29]. As shown in Figure 1, the main management server is the heart of the system and the most important part of it, which is what, distinguishes the system from the rest of the previous systems. It is responsible for organizing and managing all tasks and events within the system as a whole and making decisions for allocating blood units depending on the proposed method for allocating blood units.

The Main Management Server is designed to do the work in real-time, so most of the sub-processes were built to work semi-independent and isolated, as the main management server organizes, monitors, and coordinates the work of these processes. Example of operations:

- Reconnecting and Matching Operations: which it monitors the status of communication and provides the Support and Backup Systems, in order for the central administration server to remove the separate parties from the available storage accounts. It is also responsible for following up on the process of re-copying and matching the interruption period data between the main data store and local data stores; which the local management server performs after returning the connection.
- Status Web Management Operations: It is responsible for managing and updating the status webpage information, which displays general information about stock levels of blood units as well as information for donors about the type, quantities, and location of blood units that the system suffers from shortage on it.
- Storage Management Operations: It is responsible for following up on the changes in the storage of blood units in addition to checking the expiration date of the units.
- Blood Unit Transport Management Operations: It monitors the operations of transfusion of blood units between local blood banks to make up for the deficiency when needed.
- Create Aperiodic Request Operations: this operations follow the process of creating non-periodic allocation requests from blood requests that need periodic allocations, to adding them to the general list of requests.

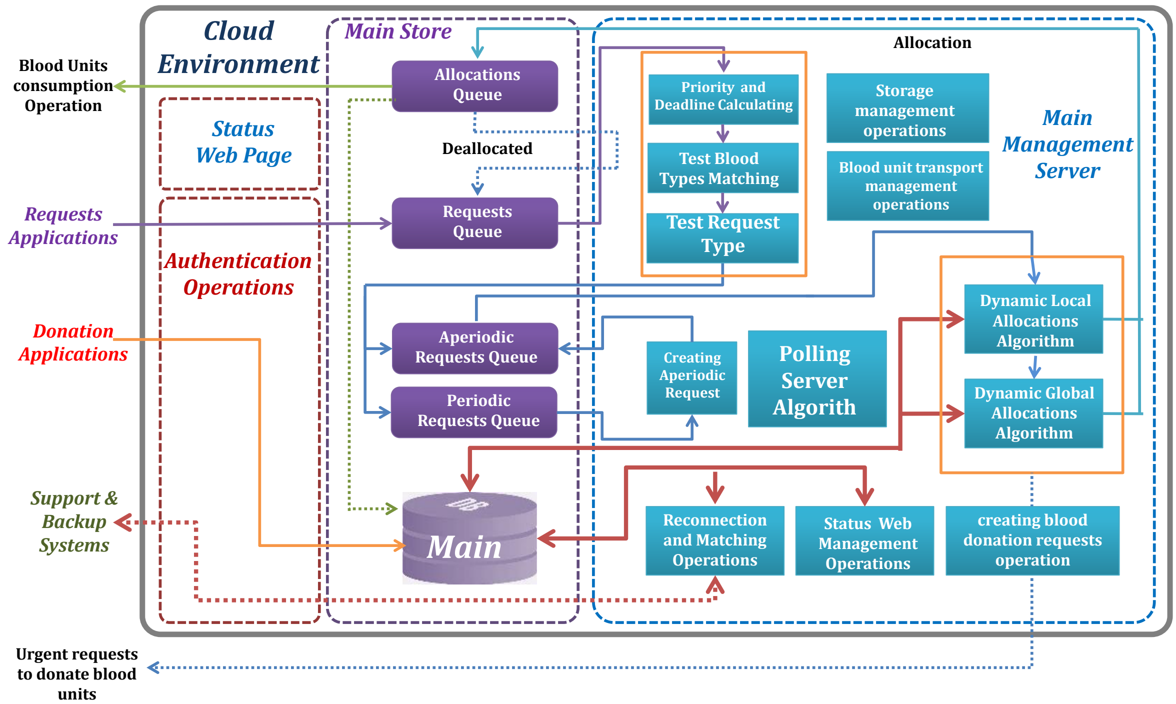

Figure 1. the Proposed System Cloud Environment

- Examination and Routing for Allocation Request: These operations perform the calculations of priority and deadline time in addition to checking and confirming the matching blood groups. It also challenges the type of request and the waiting list to be added to it.
- Moreover, the main management server contains the Dynamic Allocation Algorithms for blood units, which are responsible for allocating blood units within the system.

In addition to all of the above, the system cloud environment contains the Main Data Store which represents the main database that includes detailed information about available blood units, donors, and allocation requests for all blood banks in the system.

Also, the system cloud environment uses some of the services provided by the cloud, such as Authentication Operations, which is responsible for managing to access and authentication processes for users. As well as Status Web Page and which publishes general information about the storage level of blood units by quantity and types, along with information on blood units that need to be donated.

B. Android Application

It will be good for health care staff to be able to request the allocation of blood units or to enter newly donated blood units into the system, simply by using their portable smart devices. So, there will be two Android applications, one for the request and the second for donation, and this application will be available to everyone on the app store.

C. Support and Backup Systems

In cases of there is a connection problem with Cloud Environments or in emergency breakdowns, every local blood bank will have a local data store and a local management server. The local management services will provide the same capabilities as the main management server within a local domain. The local data store provides a secure backup storage tank for the local information. The local support and backup system will be active in emergency cases, where it will save all information about the operations within the local domain in the local data store until returned the connection with Cloud Environments, in order to be loaded in the main data store.

4. PROPOSED ALLOCATION METHOD

Blood is one of the rare and sensitive sources with a limited expiration date and one-time use, which is supplied and consumed in the system by several sources. Therefore, in the new method of allocating blood units, we railed on a hybrid of real-time resource allocation algorithms, in addition to multi-source and multi-destinations supply chain techniques. The main goal of the new method is to raise the percentage of direct allocation of blood units to consumers, based on the precedence of incoming requests and according to resources Available locally or at other blood banks in the system; all this without the any need for human intervention, to increase the speed of work and exceed the possibility of human errors. Responsibility for allocating blood units rests with the main administration server and the most important parts of this process are the Polling Server Algorithm, and the Dynamic Allocations Algorithms.

A. Polling Server Algorithm

This algorithm is responsible for managing and organizing the tasks of the main management server through the use of an algorithm similar to Polling Server, as periodic tasks will be used to serve aperiodic events. This algorithm will be responsible for arranging the sequence of execution of the server periodic tasks such as Reconnection and matching operations, Status Web Management operations, Storage management operations, and blood unit transport management operations. Besides, activate the process of creating aperiodic allocation requests from the blood requests that need periodic allocations, and adding them to the request queue. It will also be responsible for regulating the running time of the aperiodic tasks which are the Requests queue test operation, the dynamic allocation algorithms for blood units, and creating blood donation requests operation.

B. Dynamic Allocations Algorithms

These algorithms are responsible for allocating blood units, taking into account increasing the percentage of direct allocation by providing blood units for the most critical cases. We used a hybrid of real-time and supply-chain allocation algorithms to allocate blood units based on order priority and deadline time of the requests. Where, it will start searching for the appropriate unit of blood from the nearest blood bank to furthest across all blood banks. we will use two successive levels algorithms to carry do the allocation process, the first level the Dynamic Local Allocations Algorithm as shown in Figure 2, will try to provide the required blood units from the local blood bank. If the first level fails, we will move to the second level the dynamic global allocations algorithm, which will provide the required blood units by searching for it in the rest blood banks, starting from the nearest to the farthest as shown in Figure 3. Each level will use a principle of Earliest Deadline First (EDF) to allocate blood units for all allocation requests that are in the allocation requests queue. Depending on the EDF principle, the allocation request may obtain the required unit from the available units or from the units allocated to requests with the furthest deadline. In addition to the EDF principle, the priority was used to distinguish the various allocation requests and to give the allocation requests for critical cases a higher priority than other requests.

Here, we took advantage from the time between allocating and consuming blood units to reallocating blood units that allocated for lower priority requests and with the furthest deadline, to the request with high priority and closest deadline. Also, if the required blood unit replacement is not available in the blood banks in time, the system re-creates the blood unit request for the case that lost the previous allocation. Also, in the event that the required blood units are not available in the entire system, the system creates donation requests directed to the appropriate donors, depending on the type of blood unit and the location of the request.

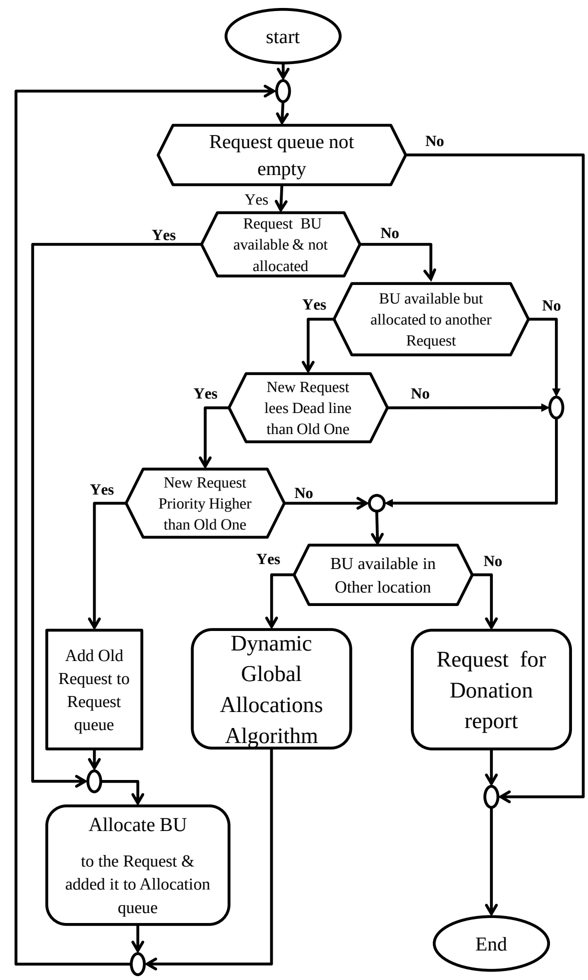

Figure 2. the Dynamic Local Allocations Algorithm

5. RESULT AND DISCUSSION

In this section, we will be shown the results obtained from the use of the new method to allocating blood units and the extent of their impact on increasing the performance relative to the results of the previous traditional methods. In general, the proposed method will still perform better than the traditional methods in terms of speed, accuracy, and transparency in the work. In addition to, eliminate the need for human intervention, which will reduce the possibility of human errors in the blood units allocating process. There are several measures to evaluate the performance of the allocating methods, the most meaningful measure we will rely upon to evaluate the performance in this paper is the percentage of failing in allocation before crossing the deadline for each method, which called Missed Allocation (MA) of blood units.

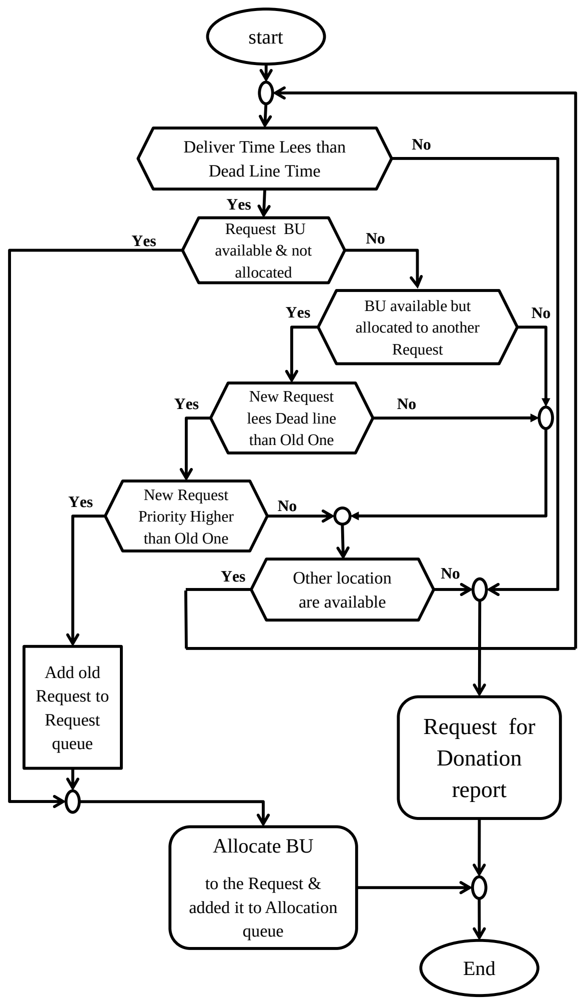

Figure 3. the Dynamic Global Allocations Algorithm

When traditional method is in use, in the usual situation, the patient is often required to offering a number of donors' equivalent to the number of blood units that will be allocated to him, which is relatively acceptable because the donation can be made after the allocation process. In the MA case, patients and their families will be asked to offering a number of donors' equivalent to the number and type of blood units that needed to allocate for him. So, here the operation of providing blood units in the required quantity and type will become the patient's problem. This may endanger the patient's life, especially if the allocation request is for critical cases.

The traditional method deals with this problem through the use of the safe backup stock of blood units. Where it will keep a number of blood units and use it for allocate to critical cases only. But this solution will not provide blood units for other cases, in addition to the need to provide this safe backup stock in every blood bank which is very expensive. In both cases, this matter greatly affects the performance of the blood unit allocation process and may lead to failure in providing blood units to the patients in some cases. And this is one of the major critical problems that will be addressed by reducing the MA rate when using the new method, with the possibility of using a virtual central safe backup stock of blood units, to serve all allocation points.

To illustrate the process we will use a simplified hypothetical example of the unit allocation process. Where the example will include requests received for only one type of blood unit within an hour (time between 8:05 and 9:00) with arrival times, deadline times, and priorities shown in Table I. Where in this example we will have two levels of priority, the critical cases with high precedence will be given a value 1, while less important and less precedent cases will be given a value 2. Suppose that the available blood unit at the beginning of the work is 5 units, and there is 5 additional units will enter the system At 8:55. After applying the traditional method and the proposed method on the previous data, as shown in Table II, we note that the traditional method failed more than once in the allocation, while the proposed method succeeded in all allocation processes.

Table I. Allocation Requests arrival times, deadline times, and priorities for the example

Request ID	Request time	Deadline time	Priority
RQ1	8:05	9:00	2
RQ2	8:10	8:40	2
RQ3	8:15	8:55	2
RQ4	8:20	8:20	1
RQ5	8:25	9:05	2
RQ6	8:30	8:50	2
RQ7	8:45	8:45	1
RQ8	8:50	8:50	1
RQ9	8:55	9:25	2
RQ10	9:00	9:00	1

In practical reality, the process is more complex than that, as we have eight types of blood units that can be allocated in a somewhat overlapping manner and a more number of levels of priorities and different types of blood units allocating requests. In addition, we will work within a longer time period and a wider geographical range. This matter greatly contributed to a positive increasing in the performance of the proposed method with improving its results. Where, as the greater the volume of data processed, in quantities and types, in the proposed method, the greater the possibility of maneuvering abilities in re-allocating blood units to the requests in a better manner. Unlike the situation when using the traditional method, the performance begins to deteriorate due to the adoption of the traditional method on human intervention and distributed safe backup stock of blood units, where when the volume of data increases in quantity and type, the work pressure on the employee in charge of the allocation process will increase.

Table II. Results of Applying Traditional method and Proposed method

Run time	Traditional method		Proposed method	
	Allocation	Notes	Allocation	Notes
8:05	RQ1		RQ1	
8:10	RQ1, RQ2		RQ1, RQ2	
8:15	RQ1, RQ2, RQ3		RQ1, RQ2, RQ3	
8:20	RQ1, RQ2, RQ3. RQ4		RQ1, RQ2, RQ3, RQ4	
8:25	RQ1, RQ2, RQ3, RQ4, RQ5		RQ1, RQ2, RQ3, RQ4, RQ5	
8:30	RQ1, RQ2, RQ3, RQ4, RQ5		RQ2, RQ3, RQ4, RQ5, RQ6	RQ1 Deallocated
8:45	RQ1, RQ2, RQ3, RQ4, RQ5	RQ7 Missed	RQ2, RQ3, RQ4, RQ6, RQ7	RQ5 Deallocated
8:50	RQ1, RQ2, RQ3, RQ4, RQ5	RQ6 and RQ8 Missed	RQ2, RQ4, RQ6, RQ7, RQ8	RQ3 Deallocated
8:55	RQ1, RQ2, RQ3, RQ4, RQ5, RQ9		RQ2, RQ4, RQ6, RQ7, RQ8, RQ3, RQ5, RQ1, RQ9	
9:00	RQ1, RQ2, RQ3, RQ4, RQ5, RQ9, RQ10		RQ2, RQ4, RQ6, RQ7, RQ8, RQ3, RQ5, RQ1, RQ9, RQ10	

As a practical application, we used the data of the main blood bank in Mosul city, to compare between the results of the traditional method with the results obtained from the same data when applying the proposed method. Where, the total rate of MA when using the traditional method ranged from 15% to 19%, and the MA rate for critical cases was about 8%. When we applying the proposed method to data of one month within the range of one blood bank, and the total MA ratio was 11%, and it was for critical cases 2.8%. Whereas when applying the proposed method to one month's data within the range of tow blood banks, the total MA ratio decreased to reach 9.2%, and the MA ratio for critical cases reached 2%. This decrease in MA rates continued in every time we increased the number of blood banks range entering the process. Where the total MA rate with the data of the one month and five blood banks range reach approximately 8% and the MA ratio for critical cases is about 1.2%, as shown in Figure 4. This is very influential results in raising the level of healthcare, due to the importance of the blood allocation process and its great impact on preserving patients' life.

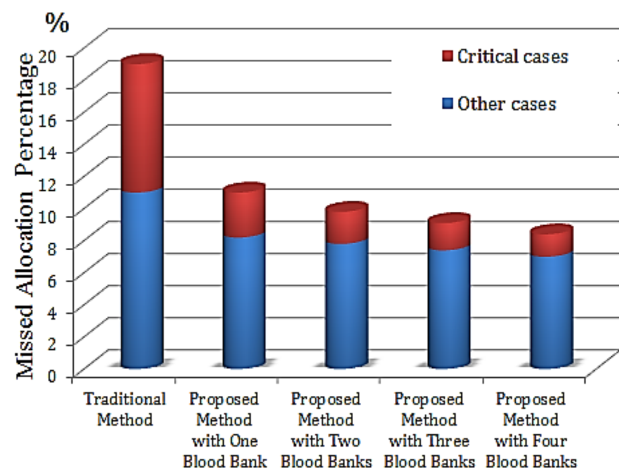

Figure 4. Missed Allocation Percentage for Traditional and Proposed methods

6. Conclusion

The use of the proposed method for allocating blood units will greatly increase the percentage of patients receiving appropriate blood units at the right time, and this is especially for critical cases. Where the proposed method will reduce the MA rates in general for all allocation requests and will also more reduce the MA rates for critical cases significantly. Therefore, we will greatly guarantee that the blood units available at the present time will be allocated in the most appropriate way possible to the allocation requests that have been received. Also, the chances of human errors occurring when performing the allocation process for blood units will become almost non-existent.

The use of the proposed method will provide the ability of central management of the allocating of blood units within the number of blood banks, hospitals, and blood donation camps. This is instead of the traditional method that adopts isolated work for every one of these components. This will provide greater opportunities for providing the required blood units, so if the allocation cannot be provided at the request position, the matching blood units will be searched and allocated from other nearest positions. This will lead to reducing the number of blood units designated as a safe backup stock of blood units, as the need for it will be greatly reduced.

In the proposed system, it will be easy to modify and develop the proposed method in order to increase the performance of the system as a whole or to deal with special emergency cases. Where, this can be done by modifying algorithms to improve their performance or adding other algorithms to deal with other various cases. This is what we noticed when we added an algorithm to allocating convalescence plasma for severe COVID-19 patients. This makes the proposed system and the proposed method for allocating blood units a solid base for building future systems that are broader and more comprehensive and able to deal with and contain all exceptional circumstances.

All this will lead to the development and improvement of health care services provided to beneficiaries. Where, the proposed method will increase the speed of implementation, raising the performance, and reducing the effort required to conduct allocation processes. Which will provide a better service while facilitating and accelerating the work of health care staff, in addition to, significantly reducing the cost of providing health care services in general.

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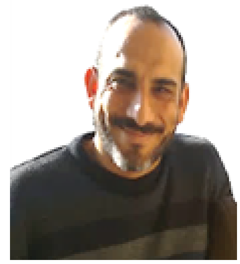

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