DESIGN AND PERFORMANCE ANALYSIS OF A RESOURCE MANAGEMENT PLATFORM IN RESPONSE TO EMERGENCY AND DISASTER SITUATIONS

by

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ABSTRACT

DESIGN AND PERFORMANCE ANALYSIS OF A RESOURCE MANAGEMENT PLATFORM IN RESPONSE TO EMERGENCY AND DISASTER SITUATIONS

This thesis focuses on the development and use of algorithms that address the issue of resource management in response to emergency and disaster situations. The presented system, named Disaster Management Platform (DMP), takes the data from the data sources of service providers and distributes the incoming requests accordingly both to manage load balancing and minimize service time, which results in improved user satisfaction. Three different resource management algorithms, which give different levels of importance to load balancing and service time, are proposed for the study. The first one is the Minimum Distance algorithm, which assigns the request to the closest resource. The second one is the Minimum Load algorithm, which assigns the request to the resource with the minimum load. Finally, the last one is the Hybrid algorithm, which combines the previous two approaches. The performance of the proposed algorithms is evaluated with respect to waiting time, success ratio, and maximum load ratio. The metrics are monitored from simulations, to find the optimal scheme for different loads. Two different simulations are performed in the study, one is time-based and the other is request interarrival time-based. The results indicate that, the Minimum Load algorithm is generally the best in all metrics whereas the Minimum Distance algorithm is the worst in all cases and in all metrics. The leading position in performance is switched between the Minimum Distance and the Hybrid algorithms, as request interarrival time values change.

ÖZET

ACİL DURUM VE AFET MÜDAHALELERİ İÇİN KAYNAK YÖNETİMİ PLATFORMUNUN GELİŞTİRİLMESİ VE PERFORMANS ANALİZİ

Bu çalışmada acil durum ve afet müdahalelerinde kaynak yönetimi sorununu ele alan algoritmaların geliştirilmesi ve kullanılması üzerinde durulmuştur. Sunulan sistem, Afet Yönetim Platformu (AYP), servis sağlayıcıların veri kaynaklarından veri almakta ve buna bağlı olarak gelen istekleri mümkün olabildiğince yük dengesini korumaya ve hizmet süresini minimize etmeye çalışarak tahsis etmektedir. Çalışma için, yük dengesine ve hizmet süresine farklı derecede önem veren, üç değişik kaynak yönetimi algoritması önerilmiştir. İlki, gelen isteği en yakın kaynağa tahsis eden Minimum Uzaklık algoritması. İkincisi, gelen isteği yükü en az olan kaynağa tahsis eden Minimum Yük algoritması. Sonuncusu, önceki iki algoritmayı birleştiren Karma algoritma. Önerilen algoritmaların performansı bekleme süresi, başarı oranı ve maksimum yük oranına göre değerlendirilmiştir. Farklı yüklere karşı ideal düzeni bulmak için ölçümler simulasyonlardan izlenmiştir. Çalışmada biri zaman tabanlı diğeri ortalama istek geliş süresi tabanlı iki farklı simulasyon gerçekleştirilmiştir. Sonuçlara göre Minimum Yük algoritması genellikle tüm ölçümlerde en iyi olduğu halde, Minimum Uzaklık algoritması her durumda ve tüm ölçümlerde en kötü olarak belirlenmiştir. Performansta lider konum, ortalama istek geliş süresi değerleri değiştikçe, Minimum Uzaklık ile Karma algoritmalar arasında değişmektedir.

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LIST OF SYMBOLS

$E[w]$	Expected waiting time
R	Set of resources
R_{int}	Request interarrival time
R_{num}	Number of requests that arrive in each batch
S	Service time
α	Exponential factor for the load ratio affecting service time
β	Waiting time threshold
γ	Batch size distribution mean
λ	Request interarrival time distribution mean
μ	Service time distribution
ρ	Load ratio
σ	Batch size distribution standard deviation

LIST OF ACRONYMS / ABBREVIATIONS

DMP	Disaster Management Platform
DS	Data Sources
DV	Disaster Victims
Min *d*	Minimum Distance
Min *k,p*	Hybrid
Min *p*	Minimum Load
MNO	Mobile Network Operators
SP	Service Providers
Std. Dev.	Standard Deviation

1. INTRODUCTION

1.1. Introduction

Disasters, either natural or human-caused, impact on entire communities and they all have significant devastating effects (Barbarosoğlu and Arda, 2004; IFRC, 2010). The immediate effects include loss of life and damage to property, with the survivors some of whom may have been injured in the disaster. The disaster may also destroy essential infrastructure such as hospitals, roads, etc., resulting in a lack of emergency. Therefore, to respond to a disaster as rapidly and effectively as possible by mobilizing the resources and using the network in a coordinated manner is required to counter the initial effects (IFRC, 2010; Thompson *et al*., 2006).

Effective disaster management and response demands timely, dynamic and accurate utilization of information and data from many sources (Altay and Green, 2006; Hristidis *et al*., 2010; Laituri and Kodrich, 2008). It is more than just response and relief; it assumes a more proactive approach. Disaster management is a systematic process, based on the significant management principles of planning, organizing, and leading which includes coordinating and controlling. It aims to provide services and assistance so as to reduce the negative impact or consequences of adverse events in the most efficient way possible (Shah *et al*., 2013; VUSSC, 2010).

In attempting to achieve this goal, a number of different human and physical resources such as rescue teams, health personnel, hospital bed, food, tents, etc. need to be identified and managed by the disaster response agencies. The quantity and capacity of these resources, besides their location and availability, should be known and continuously controlled. The agencies also need to work collaboratively so as to deploy them appropriately. All of these factors are critical since resources provided too late or too early and/or insufficiently or exceedingly can reduce the effectiveness of recovery (Fiedrich and Burghardt, 2007; Shah *et al*., 2013). Definitely, the response planners should possess robust and generic decision tools and models to enhance their disaster relief and response capability (Barbarosoğlu and Arda, 2004).

1.2. Rationale of the Thesis

The area of disaster management receives increasing attention from multiple disciplines of research; computer science is not an exception. The vital role of the computer scientists has been devising ways to analyze the data produced in disaster management situations and produce prompt response to manage the resources and the crisis efficiently (Hristidis *et al.*, 2010).

To this end, it is crucial to gather up-to-date information regarding the resources provided and the demand from the victims of the disaster.

1.3. Statement of the Thesis

This thesis focuses on the development and use of algorithms that address the issue of resource management in response to emergency and disaster situations.

It is not limited to a particular kind of disaster and considers all types of disasters, which can be geophysical (earthquakes, landslides, tsunamis and volcanic activity), hydrological (avalanches and floods), climatological (extreme temperatures, drought and wildfires), meteorological (cyclones and storms/wave surges), biological (disease epidemics and insect/animal plagues), technological (complex emergencies/conflicts, famine, displaced populations, industrial accidents and transport accidents), or other man-caused disasters (leakage from chemical or nuclear plants, NBC attacks).

We present a system, named *Disaster Management Platform (DMP),* which takes the data from related institutions (e.g., Crisis Management Desk, Ministry of Health, Municipality, etc.) and distributes the incoming requests accordingly, both to manage load balancing and minimize service time which results in improved user satisfaction.

1.4. Goals and Objectives

The main goal of DMP is to assign the resources in efficient and fair way. While assigning services and routing, the objective is to minimize the transportation and waiting time in the queue (i.e., average total time to get service), along with keeping the resources from getting overloaded (minimizing the maximum load).

1.5. Method of the Thesis

We model the inflow and outflow of the system and propose different resource management algorithms, which give different levels of importance to load balancing and service time.

We evaluate the performance of the algorithms with respect to waiting time, success ratio, and maximum load ratio. The metrics are monitored from simulations, to find the optimal scheme for different loads.

The proposed DMP system also pays attention to practical issues to render useful. The interaction with the disaster victims is based on trivial SMS messages rather than any pre-installed application and does not require any pre-registration. Thus, everyone with a cellular phone in the disaster area can benefit from the system, regardless of phone type (no need for smartphones) and subscription.

Furthermore, the privacy of the disaster victim is respected. The service providers do not know the identity of the victim; the reservations and services are executed by exchanging reservation tokens.

1.6. Outline of the Thesis

The thesis is organized as follows:

Some relevant background is given in the next chapter and a review of the literature is detailed in the consequent chapter.

The methodology of the system is in third chapter, in which the model of the system is described. It also introduces the problem and identifies the algorithms.

The fourth chapter is implementation; metrics and simulation parameters are stated. The performance evaluation of the proposed algorithms is discussed and the computational results are analytically presented in this chapter.

Finally, the last chapter provides some concluding remarks and future directions.

2. BACKGROUND

2.1. Emergency and Disaster Situation

In order to define *emergency and disaster situation*, at first it is needed to understand the meaning of hazard. Hazards are potential physical instances, phenomenon or human activity that can harm a community and create damage to its infrastructure (PSC, 2011; VUSSC, 2010). The Cambridge Dictionary online (2014) and The Merriam-Webster Dictionary online (2014) also associate hazards with danger (an instance likely to cause damage) and risks (probabilities of events to produce harm or create damage).

Emergency and disaster situations result when a hazard interacts with a vulnerability to produce serious and adverse consequences that may, for an undetermined period of time, exceed the ability to cope with the situation; therefore, incurs in loss of life and/or damage to infrastructures (IFRC, 2010; PSC, 2011). The situation can be motivated by the geophysical or biological environment (natural disaster) or by human action or error (man-made disaster) (PSC, 2011; VUSSC, 2010).

Paying immediate attention to an event or situation is important as the event/situation can generate negative consequences and escalate into an emergency. A hazard can become an emergency; when the emergency moves beyond the control of the population, it becomes a disaster (VUSSC, 2010).

An emergency event represents a present or imminent disaster or extreme event, which prompts co-ordinated actions among people and organizations in order to protect life and/or property or reduce death and/or damage. Emergency events necessarily involve response and coordination towards risk reduction (for imminent disasters) or impact reduction (for present disasters) (Ferreira, 2010).

2.2. Emergency and Disaster Response

Emergency and disaster response is the sum total of actions taken by people and institutions in the face of emergency and disaster situation (VUSSC, 2010). It is the most critical phase when emergency and disaster management agencies attempt to provide services and assistance so as to save lives, reduce the impacts on health, make sure that basic security and subsistence needs are met (Fiedrich *et al*., 2000; Shah *et al*., 2013).

Emergency and disaster response efforts consist of two stages; pre-event and post-event response. Pre-event tasks include predicting and analyzing potential dangers and developing necessary action plans for mitigation. Post-event response starts while the disaster is still in progress. At this stage the challenge is locating, allocating, coordinating, and managing available resources (Tüfekçi and Wallace, 1998).

There are different types of communities that require emergency and disaster data management tools and systems to report on the current situation, share infrastructure and resource data, and exchange other emergency communications (Hristidis *et al*., 2010).

These organizations usually aim at reducing potential impacts associated with the occurrence of an extreme event according to specific situations, conflicting priorities and resources limitations (Ferreira, 2010). Such assistance may range from providing specific but limited aid, such as assisting refugees with transportation, temporary shelter, and food, to establishing semi-permanent settlement in camps and other locations. It also may involve initial repairs to damaged infrastructure (VUSSC, 2010).

They also aim at operational co-ordination among public organizations (e.g. Fire, Ambulance, Councils) and private services (e.g. Power, Water, Telecommunications). Thus, response and restoration times can be reduced as well as resources used at optimum levels (Ferreira, 2010).

Making timely and effective use of available resources can minimize the number of fatalities and improve the likelihood that injured victims will survive (Thompson *et al*., 2006).

2.1.1. Resource Management

Resource management is a critical component of emergency and disaster preparedness and response (Pesik and Keim, 2002). Also, disasters present challenges for resource management that are different from those in routine emergencies (Auf der Heide, 1989). Hence, the decision-making process during a disaster response differs drastically from conventional decision-making (Jianshe *et al.*, 1994).

In emergency and disaster response situations important attributes of the problem are uncertain (e.g. its nature, scale, time etc.). The problem environment is changing rapidly and uncontrollably. There is very little time for making a decision but information might not be available (or, even if available, might not be reliable). Lastly, some critical disaster response decisions might be irreversible (Pauwels *et al*., 2000).

Moreover, in major disaster events, actual disaster impact damages or destroys local resources reducing available resources to respond and also significantly increases the workload of the existing resources. Therefore, the use of resources (personnel, facilities, supplies and equipment) from multiple jurisdictions may be required. This leads to the assumption that the primary problem in disaster planning is the mobilization of enough resources (Quarantelli, 1983). Based on this assumption, disasters have even been defined as emergencies that exceed the available resources (Orr and Robinson, 1983).

The inflow of resources to the impacted jurisdiction however, can complicate the already difficult problems of coordination and communication if the inflow is greater in amount than needed (Stout and Smith, 1981). Ideally only needed resources should be requested and delivered. Unsolicited aid can often hamper an emergency and disaster response (Pesik and Keim, 2002).

The ability to deliver the right supplies, in the right quantity, and to the right place is the goal of an effective emergency and disaster response operation (UNHCR, 2007). For an effective resource management, determining which resources are needed and how to procure them is required as well as identifying a means to transport these resources where they are needed. There is also need to develope a system that distributes the assistance to affected persons. This system should ensure that the supplies and resources are distributed equitably and to the needed areas (PAHO, 2000).

It is important that disaster planners and emergency coordinators develop procedures for multi-agency management of resources so that requests are coordinated. Resources need to be classified so that they can be meaningfully, optimally and quickly allocated (Auf der Heide, 1989).

3. REVIEW OF THE LITERATURE

In the literature, the research area of resource management mostly deals with defining procedures to supply immediate need in the disaster location by utilizing all available resources in an efficient and timely manner. There exist different methods of performing operations.

According to Li *et al.* (2009), emergency resource scheduling is the most important component of emergency management system. Their approach is based on the transport path optimization. The optimization includes fuzzy logic and mutations to avoid local maxima and to indicate the validity of the solutions in hand. Thus, it is possible to have an idea on the probability of having the best result possible, aiming to find the optimized path optimization.

Zhou and She (2011) determine two solutions of emergency resource distribution. The first one is the single-save point and multi-disaster point integer programming model which offers three cases to determine the optimization distribution solution, and uses some optimization software to solve the types and quantities of resource distribution. The other one is the multi-depot and single-disaster point model in which different emergency resource suppliers allocate resources to more complex disaster areas, and TOPSIS method is adopted to solve it. TOPSIS considers distance to positive and negative results to determine the correctness of the solution.

The proposed method of Sheu *et al.* (2005) utilizes a three-stage algorithm. Firstly, fuzzy logic is used to cluster the disaster areas, according to their priorities. Then, fuzzy linear programming is used to handle the demand by users, which extends the resources. The results show the applicability of the current method.

Su *et al.* (2011) propose a path selection algorithm based on Q-learning. A path selection model is offered first. The path selection is made through a Markov decision process. Here, Q-learning provides the selection of action and avoidance of cyclic path.

Xiong and Shi (2011) build a multi-emergency point schedule model and provide a solution based on a dynamic optimization strategy.

Yongjun *et al*. (2010) first use a grey prediction model to allocate resources and then formulate a dynamic multi-objective resource scheduling problem to dispatch allocated resources to a single sink. The resources are assumed to be consumed based on a given rate and are replaced as necessary.

Yuan and Wang (2009) present two mathematical models for path selection in emergency logistics management. One is single-objective path selection model, which is to minimize total travel time along the path. They design a modified Dijkstra algorithm to solve the model. The other is multi-objective path selection model, which is to minimize the total travel time along the path and the path complexity. They use ant colony optimization algorithm to solve the model.

Chiou and Lai (2008) offer an integrated multi-objective model to determine the optimal rescue path. It consists of three sub-models: rescue shortest path model, post-disaster traffic assignment model, and traffic controlled arcs selection model. The objective is to minimize travel time of rescue path, total detour travel time, number of unconnected trips of non-victims, and number of police officers required. They use genetic algorithms and *K*-shortest path methods to determine optimal rescue path and controlled arcs, and use fuzzy system reliability theory (weakest *t*-norm method) to measure the access reliability of rescue path.

According to Friedrich *et al*. (2000), it is important to make an optimal schedule to distribute the resources after the disaster. To manage this, all the incoming information should be processed by a computer-based decision making system. The disaster area is divided into search-and-rescue (SAR), stabilizing, and immediate rehabilitation areas. SAR is the area in which the initial search and rescue operations are executed. Stabilizing areas is where the people are exposed to the secondary disasters, such as damaged buildings. Here, stabilizing is used in the sense of stabilizing the number of injured, which may be caused by the mentioned secondary disasters. Immediate rehabilitation areas is where the road infrastructure has to be repaired to make the other areas accessible. The proposed model has the aim of minimizing the number of injured people who have not received aid subject to the resources in hand, their transportation times, and the losses that might occur in case of latencies. Even the period that the services are conveyed to the disaster victim is important.

Yi and Özdamar (2007) separate the problem of managing logistics in the case of a disaster into Location Routing Problem (LRP) and Vehicle Routing Problem (VRP). The problem of managing logistics in the case of a disaster is about placing the temporary medical centers in the correct places and then routing the vehicles correctly. The aim of LRP is to minimize the transportation delay, and the aim of VRP is to make the deliveries/pick-ups in an optimized way, to fulfill the requests in a timely manner. The objective is to minimize the weighted sum of the unsatisfied demand over all commodities. The capacities of the vehicles, transportation delays, and other waiting times are considered as constraints. Also, routes for the vehicles are constructed; the order of the points where those vehicles should stop is set.

Yi and Kumar (2007) consider also heterogeneous vehicles. To solve the Integer Linear Programming (ILP) formulated problem of logistics distribution, load balancing, and vehicle routing, the paper proposes an ant colony approach. The ant colony approach includes reinforcing the paths that bring high utility. The paths are probabilistically built at the beginning so that local maxima are avoided. Then, the paths with higher utility are used again and again, which triggers the other solutions to use the same path. This way, the solution space is explored efficiently.

Albareda-Sambola *et al.* (2005) mention a combined location-routing problem. They define an auxiliary network and formulize the problem in a compact way to find a set of paths in the auxiliary network.

Özdamar *et al.* (2004) say that dispatching commodities is a part of logistics planning in emergency state. A planning model to be integrated into a natural disaster logistics support system is designed. The model combines the multi-commodity network flow problem and the vehicle routing problem. Here, vehicles are also treated as commodities.

Belenguer *et al.* (2000) mention the Split Delivery Vehicle Routing Problem (SDVRP), a relaxation of the Capacitated Vehicle Routing Problem (CVRP) in which it is possible to service the demand of a client by more than one vehicle. A feasible solution to this problem is proposed.

Toregas *et al.* (1971) take the problem of locating the emergency facilities as a set covering problem. Each demand point is represented as a constraint which is solved using linear programming.

Hakimi (1965) considers a graph with multiple medians (following the concept of median in weighted graphs). Then, the optimum distribution of p switching centers is shown to be at a p-median of the corresponding weighted graph.

Although resource management procedures are vital in quickly responding to the disaster, the research on this area is not prevalent enough. Moreover, it is evident that there is the need for effective programs focused to address actions of the first responders, to reduce the confusion, insure efficiency, and begin the recovery process. Therefore, developing resource management procedures in response to emergency and disaster situations is a workable area for research.

4. METHODOLOGY

4.1. System Model

The proposed Disaster Management Platform addresses the chaos of resource management in the aftermath of an emergency and disaster situation, by gathering up-to-date information regarding the resources provided and the demand from the victims of the disaster.

4.1.1. System Dynamics

The dynamics of the system are described in Figure 4.1.

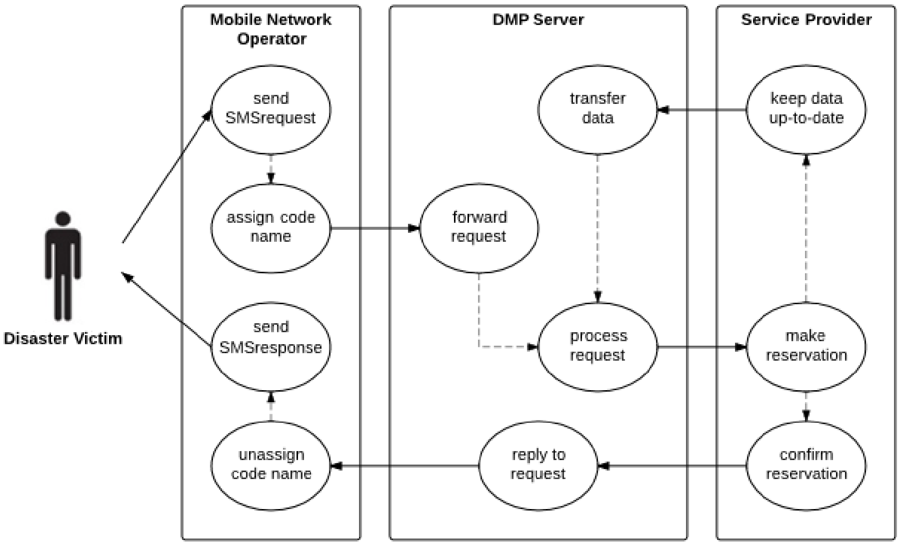


Figure 4.1. Dynamics of the system DMP.

In this model, the server of the system (DMP Server) gets the necessary information from the Data Sources (DS) of the Service Providers (SP) where the reservations and the confirmations are made. Then, it distributes the incoming requests of the Disaster Victims (DV) accordingly both to manage load balancing and minimize service time. There also exists Mobile Network Operators (MNO), as the medium between the DV and the DMP Server, by which the requests from the DV are received.

To protect the privacy of the DV, the MNO performs an address translation by replacing the GSM number of the DV with a generic corresponding code name (e.g., DV_1), which is known only to the MNO. Consequently, it forwards the requests to the DMP Server for processing. The response of the DMP Server goes through a reverse address translation and is delivered to the DV by the MNO via SMS. We assume that the MNO takes the necessary precautions to restitute any failures in the infrastructure.

4.1.2. Request Processing Scenarios

The following scenarios explain how request processing of the system works:

(i) One sample is that, after a disaster, the DV sends an SMS request via the system. The MNO forwards the request to the DMP Server and the DMP Server firstly checks the availability of the requested resource according to the information within hand. Then, it asks the SP if the resource is still available. If so, the reservation code is generated by the SP and transmitted to the DMP Server. The DMP Server sends it back to the MNO, then the DV receives the reservation code. The resource is reserved, until the DV uses it. This scenario is set out in Figure 4.2.

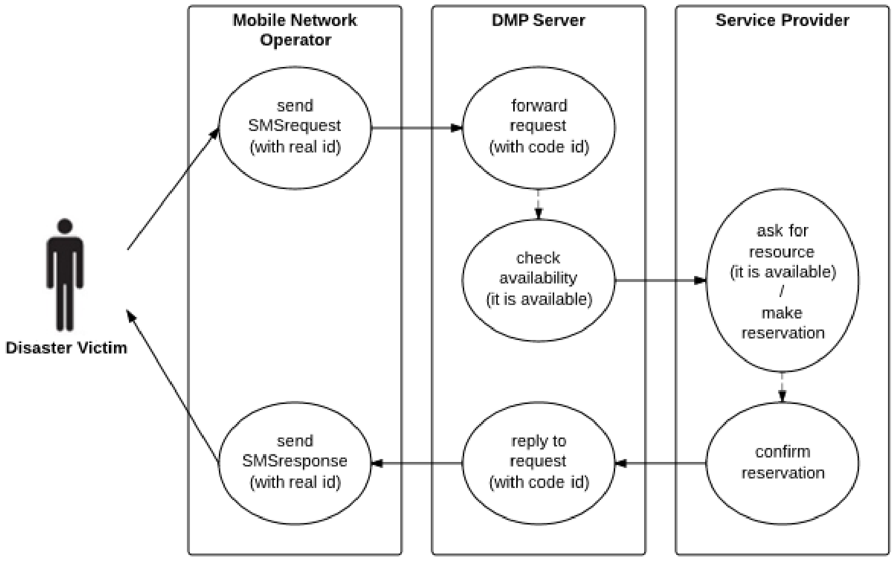


Figure 4.2. Request processing for an available resource.

(ii) Likewise, the DV makes a request. However, the resources are full and the request is queued. After the SP notifies about the discharge of the resource, the DV executes the steps in (i) in a similar way. This scenario is set out in Figure 4.3.

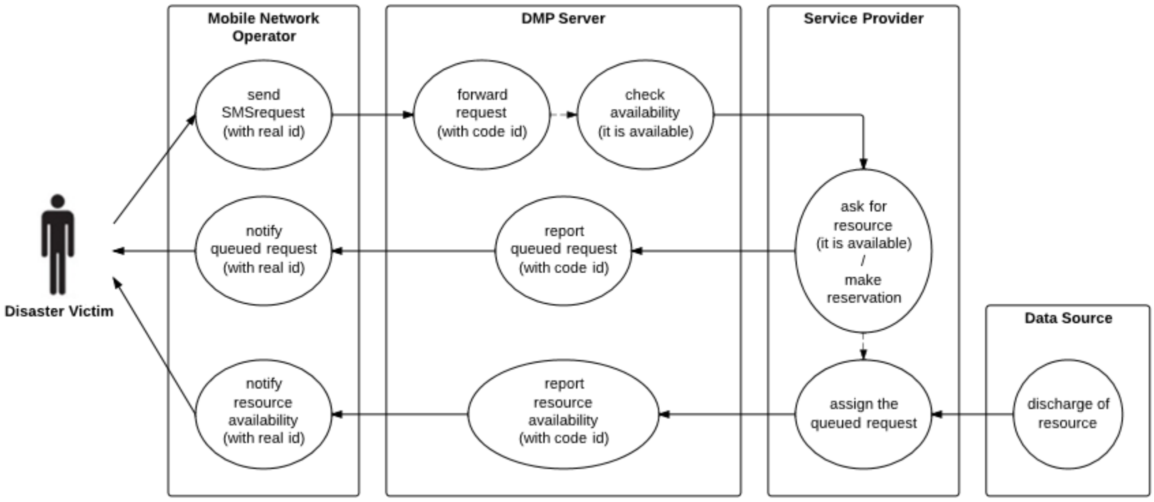


Figure 4.3. Request processing for an unavailable resource.

(iii) Similar to (i), the reservation is made. However, a cancelling message from the DV follows the same MNO - DMP Server - SP path. This sets free the resource to make others benefit. The request cancelled notifier reaches back to the DV, through the same path. This scenario is set out in Figure 4.4.

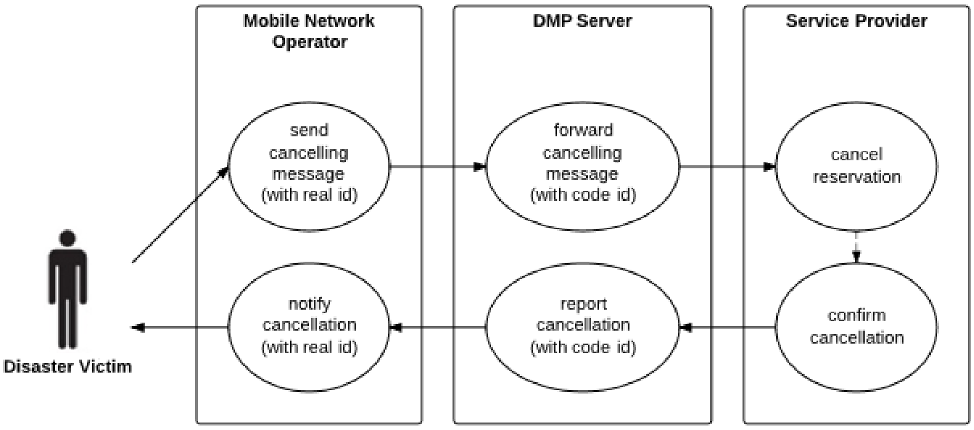


Figure 4.4. Request cancellation process.

(iv) The DMP Server questions the availability of the resources periodically. This action takes place between the DMP Server and the SP. The DMP Server asks for the status of the resource and the SP checks whether the resource is available or not, then returns with the report of the status. It is set out in Figure 4.5.

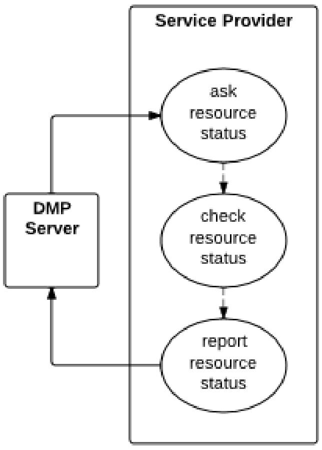


Figure 4.5. Resource status check process.

The SP also keeps the data up-to-date and transfers the updated data to the DMP Server regularly. It is also set out in Figure 4.6.

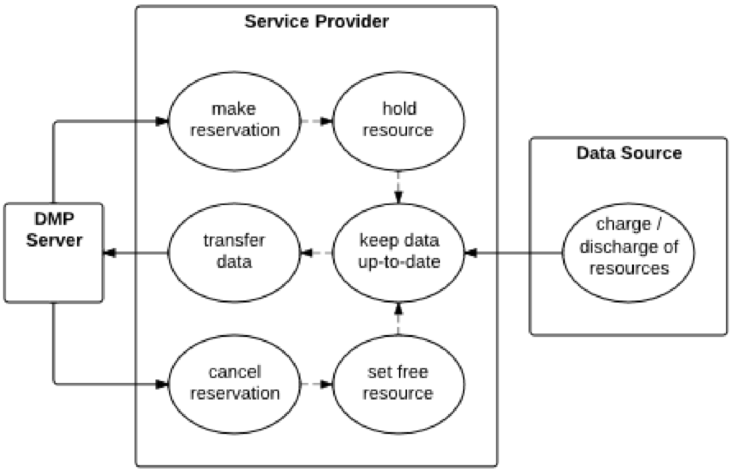


Figure 4.6. Data update and transfer process.

While all these occur, the MNO takes the role of the translator of the code id and the real telephone number. It is set out in Figure 4.7.

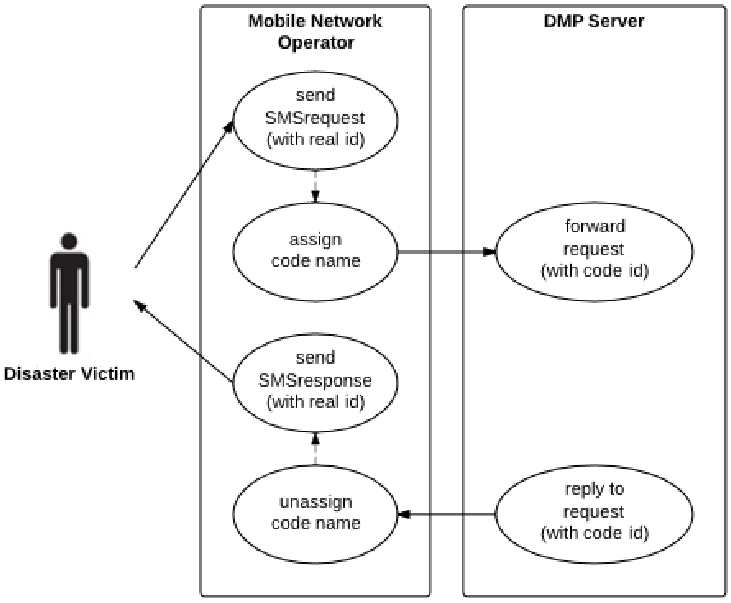


Figure 4.7. Protection of user privacy process.

4.1.3. Queuing Model

Considering the demonstration of the model, we follow the case where the requests from the DV are handled by the hospitals. We consider a scenario where the requests result from the recovery of several lives from collapsed buildings; thus, the requests arrive in batches. Therefore, the system should use the capacity of the hospitals efficiently while assigning services and routing. The aim is to minimize the transportation and waiting time in the queue while preventing overloading of the resources.

We assume that, request interarrival time (R_{int}) is exponentially distributed with mean λ, as in

$$R_{int} \sim \exp(\lambda) \qquad (4.1)$$

The number of requests that arrive in each batch (R_{num}) is normally distributed with mean γ and variance σ, as in

$$R_{num} \sim N\,(\gamma, \sigma^2) \tag{4.2}$$

The service time (S) is also exponentially distributed with mean μ. We also assume S is affected from the load ratio ρ, by an exponential factor α, because hospitals with high ρ tend to serve the arriving requests in a longer time. So, it follows that:

$$S \sim \exp \mu + \mu\rho^{\alpha} \tag{4.3}$$

4.2. The Application

We have an implementation of the project. It is the prototype of a system to be used in a disaster state. Simulations in matlab are the illustration of this system. The screenshots of the system are shown in Figure 4.8, 4.9, 4.10 and 4.11.

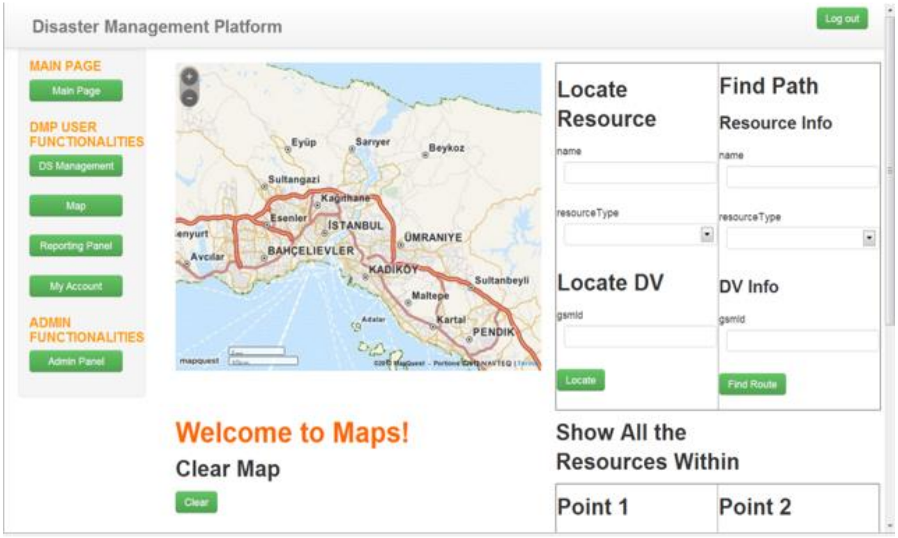
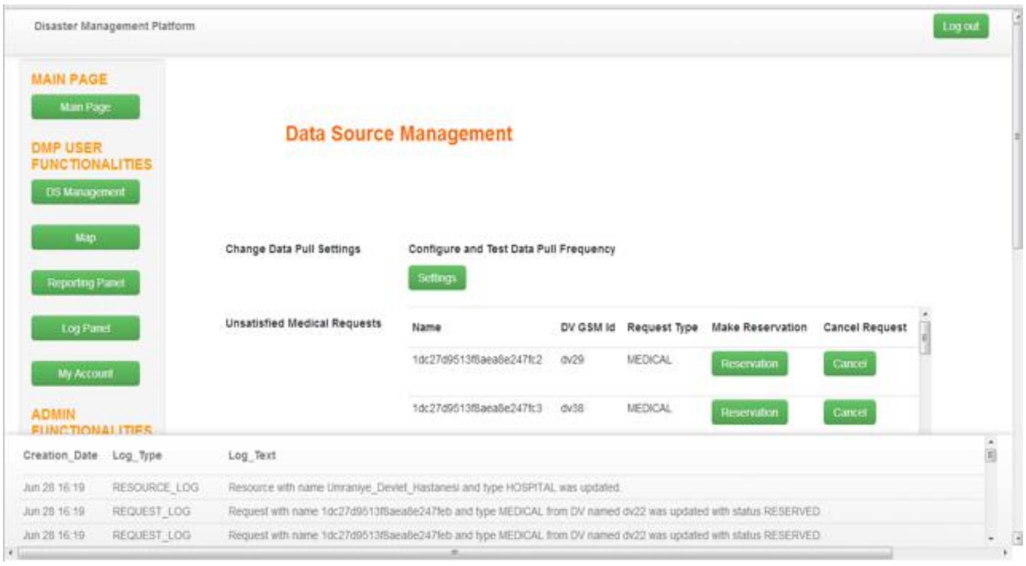


Figure 4.8. Maps.



Data Source Management

Change Data Pull Settings

Configure and Test Data Pull Frequency

Settings

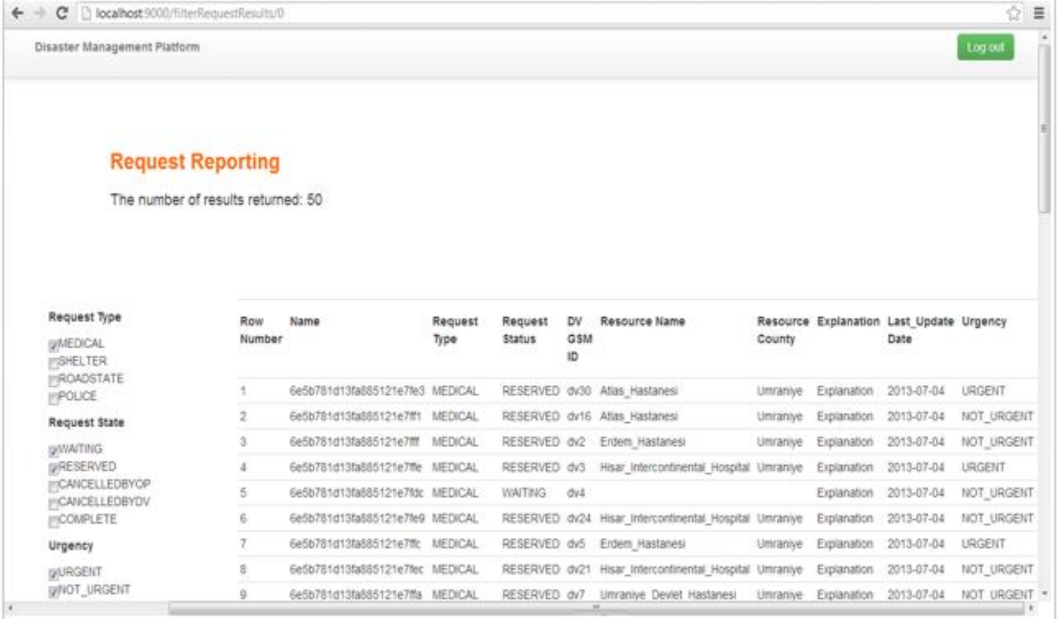
Unsatisfied Medical Requests

Name	DV GSM Id	Request Type	Make Reservation	Cancel Request
1dc27d9513f8aea8e247fc2	dv29	MEDICAL	Reservation	Cancel
1dc27d9513f8aea8e247fc3	dv38	MEDICAL	Reservation	Cancel

Creation_Date	Log_Type	Log_Text
Jun 28 16:19	RESOURCE_LOG	Resource with name Umraniye_Devlet_Hastanesi and type HOSPITAL was updated.
Jun 28 16:19	REQUEST_LOG	Request with name 1dc27d9513f8aea8e247feb and type MEDICAL from DV named dv22 was updated with status RESERVED
Jun 28 16:19	REQUEST_LOG	Request with name 1dc27d9513f8aea8e247feb and type MEDICAL from DV named dv22 was updated with status RESERVED

Figure 4.9. Data source management.

The code is written in Java, using the Play Framework. It is preferred because of it simplifies the implementation of the project, by containing all the necessary parts for a framework. It is based on the MVC (Model-View-Controller) scheme, to seperate the different parts of the project. This also eases the implementation.



Request Reporting

The number of results returned: 50

Request Type

☑MEDICAL
☐SHELTER
☐ROADSTATE
☐POLICE

Request State

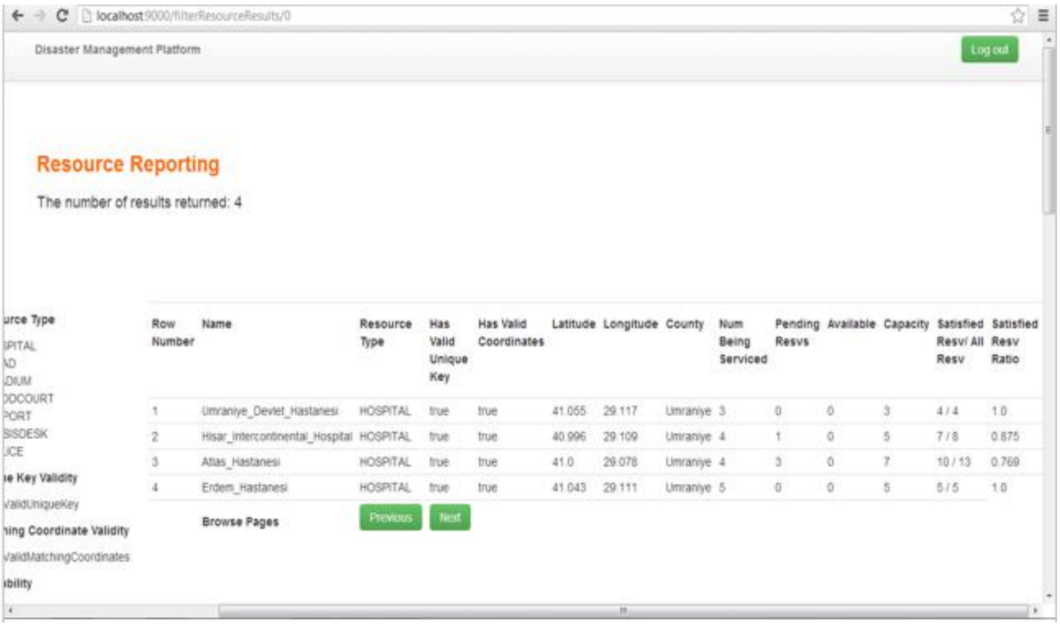
☑WAITING
☑RESERVED
☐CANCELLEDBYOP
☐CANCELLEDBYDV
☐COMPLETE

Urgency

☑URGENT
☑NOT_URGENT

Row Number	Name	Request Type	Request Status	DV GSM ID	Resource Name	Resource County	Explanation	Last_Update Date	Urgency
1	6e5b781d13fa885121e7fe3	MEDICAL	RESERVED	dv30	Atlas_Hastanesi	Umraniye	Explanation	2013-07-04	URGENT
2	6e5b781d13fa885121e7ff1	MEDICAL	RESERVED	dv16	Atlas_Hastanesi	Umraniye	Explanation	2013-07-04	NOT_URGENT
3	6e5b781d13fa885121e7fff	MEDICAL	RESERVED	dv2	Erdem_Hastanesi	Umraniye	Explanation	2013-07-04	NOT_URGENT
4	6e5b781d13fa885121e7ffe	MEDICAL	RESERVED	dv3	Hisar_Intercontinental_Hospital	Umraniye	Explanation	2013-07-04	URGENT
5	6e5b781d13fa885121e7fdc	MEDICAL	WAITING	dv4			Explanation	2013-07-04	NOT_URGENT
6	6e5b781d13fa885121e7fe9	MEDICAL	RESERVED	dv24	Hisar_Intercontinental_Hospital	Umraniye	Explanation	2013-07-04	NOT_URGENT
7	6e5b781d13fa885121e7ffc	MEDICAL	RESERVED	dv5	Erdem_Hastanesi	Umraniye	Explanation	2013-07-04	URGENT
8	6e5b781d13fa885121e7fec	MEDICAL	RESERVED	dv21	Hisar_Intercontinental_Hospital	Umraniye	Explanation	2013-07-04	NOT_URGENT
9	6e5b781d13fa885121e7ffa	MEDICAL	RESERVED	dv7	Umraniye Devlet Hastanesi	Umraniye	Explanation	2013-07-04	NOT URGENT

Figure 4.10. Request reporting.



Resource Reporting

The number of results returned: 4

Row Number	Name	Resource Type	Has Valid Unique Key	Has Valid Coordinates	Latitude	Longitude	County	Num Being Serviced	Pending Resvs	Available	Capacity	Satisfied Resv/ All Resv	Satisfied Resv Ratio
1	Umraniye_Devlet_Hastanesi	HOSPITAL	true	true	41.055	29.117	Umraniye	3	0	0	3	4 / 4	1.0
2	Hisar_Intercontinental_Hospital	HOSPITAL	true	true	40.996	29.109	Umraniye	4	1	0	5	7 / 8	0.875
3	Atlas_Hastanesi	HOSPITAL	true	true	41.0	29.078	Umraniye	4	3	0	7	10 / 13	0.769
4	Erdem_Hastanesi	HOSPITAL	true	true	41.043	29.111	Umraniye	5	0	0	5	5 / 5	1.0

Browse Pages

Figure 4.11. Resource reporting.

The project is the implementation of the functionalities illustrated in the model part. The different modules of the project will be installed on Mobile Operator, Disaster Management Platform and the Data Source. As mentioned, the device of the Disaster Victim does not require an application.

4.3. Problem Definition

As mentioned earlier, the system should distribute the incoming requests to hospitals in a manner such that both the waiting time for the requests and the maximum load for the hospitals are minimized.

Resource management in DMP can be expressed as a minimization problem as follows:

$$min\left(\max_{r\in R}\rho_r\right)\quad s.t.\quad E[w]<\beta \tag{4.4}$$

Here, R represents the set of resources, $E[w]$ is the expected waiting time, and β is the waiting time threshold. It is necessary to minimize the maximum load to provide decent service at the hospitals. Also, there is a threshold for the service time, because serving some medical requests after a certain interval is pointless. We consider different algorithms to show whether they meet the given constraints. does not require an application.

4.4. Resource Management Algorithms

Three different resource management algorithms, which give different levels of importance to load balancing and service time, are proposed for the study.

The first one is the Minimum Distance (Min d) algorithm, which assigns the request to the closest resource. It chooses the resource with the minimum distance, among the ones within range d. Thus, it gains from waiting time (less time overhead for travel). However, it suffers from unbalanced load at the hospitals since the hospitals closer to the disaster area get high demands, while the others remain idle. This situation overloads the closest hospitals, which also causes the service time to increase. Thus, the ratio of served requests decreases and also the efficiency of the system deteriorates.

The second one is the Minimum Load (Min ρ) algorithm, which assigns the request to the resource with the minimum load independent of the distance as long as the resource is in the travel range of the disaster victim. Therefore, the travel overhead is neglected. On the other hand, it balances the load, keeping the largest possible number of hospitals available. Despite the system gains from the balanced load and decreased service times, it loses from the travel overhead. Sending the disaster victims to the farthest hospital in range increases the waiting time.

Finally, the last one is the Hybrid (Min k, ρ) algorithm, which combines the previous two approaches. It combines Min d and Min ρ to benefit from the advantages both, the short travel time of Min d and the short service time of Min ρ. It chooses the closest hospital among k available hospitals with the smallest ρ. Increasing the number of available hospitals with the smallest ρ considered, makes the system work like Min d, whereas decreasing the number of the hospitals with the smallest ρ makes the system work like Min ρ.

5. IMPLEMENTATION

5.1. Metrics and Simulation Parameters

The metrics are monitored from simulations, to find the optimal scheme for different loads. Two different simulations are performed in the study. One is time-based which is executed with respect to time and the other is λ-based which is executed with respect to changing λ. They both include a 24-hour period. The time-based simulation executes this period 13*2=26 times (13 is the number necessary for the statistical correctness of the results and multiplying 13 by 2 is for further improvement of the results). The λ-based simulation also executes 26 times for each value of λ. Ten different λ values are used in the simulation. The averaged results are plotted with respect to time in both simulations.

The input parameters for the time-based simulation are as follows:

- Hospital Count : 100 hospitals
- Hospital Range (d) : 10 kilometers
- Area Size : 50 kilometers
- Base Mean Arrival Time : 8 minutes
- Base Request Count Mean : 160 requests
- Base Request Count Std. Dev. : 80 requests
- Mean Service Time : 64 minutes

Here, DV and hospitals are assumed to be scattered on the field uniformly. The area size and the hospital range values indicate the edge lengths of the squares representing the area and the hospital range. The exponential factor α is accepted as 2.

The Base Mean Arrival Time, Base Request Count Mean and Base Request Count Standard Deviation are mentioned on a 24-hour basis. We assume that all hospitals have some available space before the disaster.

The 24-hour time scale is divided into 6-hour periods as follows:

- 1st Period
  - (i) Mean Arrival Time = Base Mean Arrival Time
  - (ii) Request Count Mean = Base Request Count Mean * 4
  - (iii) Request Count Std. Dev. = Base Request Count Std. Dev.
- 2nd Period
  - (i) Mean Arrival Time = Base Mean Arrival Time * 2
  - (ii) Request Count Mean = Base Request Count Mean * 2
  - (iii) Request Count Std. Dev. = Base Request Count Std. Dev.
- 3rd Period
  - (i) Mean Arrival Time = Base Mean Arrival Time * 4
  - (ii) Request Count Mean = Base Request Count Mean
  - (iii) Request Count Std. Dev. = Base Request Count Std. Dev.
- 4th Period
  - (i) Mean Arrival Time = Base Mean Arrival Time * 2
  - (ii) Request Count Mean = Base Request Count Mean * 2
  - (iii) Request Count Std. Dev. = Base Request Count Std. Dev.

The input parameters for the λ-based simulation are as follows:

- Hospital Count : 100 hospitals
- Hospital Range (d) : 10 kilometers
- Area Size : 50 kilometers
- Base Mean Arrival Time : 8 minutes
- Base Request Count Mean : (20,40,…,200) requests
- Base Request Count Std. Dev. : (10,20,…,100) requests
- Mean Service Time : 64 minutes

For Base Mean Arrival Time and Mean Service Time, 8 and 64 were chosen, because we use Mean Arrival Times of 2*Base Mean Arrival Time and 4*Base Mean Arrival Time. We set the mentioned values to be equal to 2^n for some $n \in N$.

The metrics examined are average waiting time, success ratio, and max ρ. Average waiting time is the expected waiting time of a request in a queue, starting from the time that it has been assigned to a resource. Also, the time on the road (calculated according to the distance) and the service time S are added to the average waiting time. Success ratio is the number of served requests divided by the total number of received requests. Max ρ is the maximum load ratio, which needs to be minimized.

5.2. Performance Evaluation

The performance of the proposed algorithms is evaluated with respect to waiting time, success ratio, and maximum load ratio.

5.2.1. Time Analysis

The performance of the algorithms with respect to the metric average waiting time is shown in Figure 5.1.

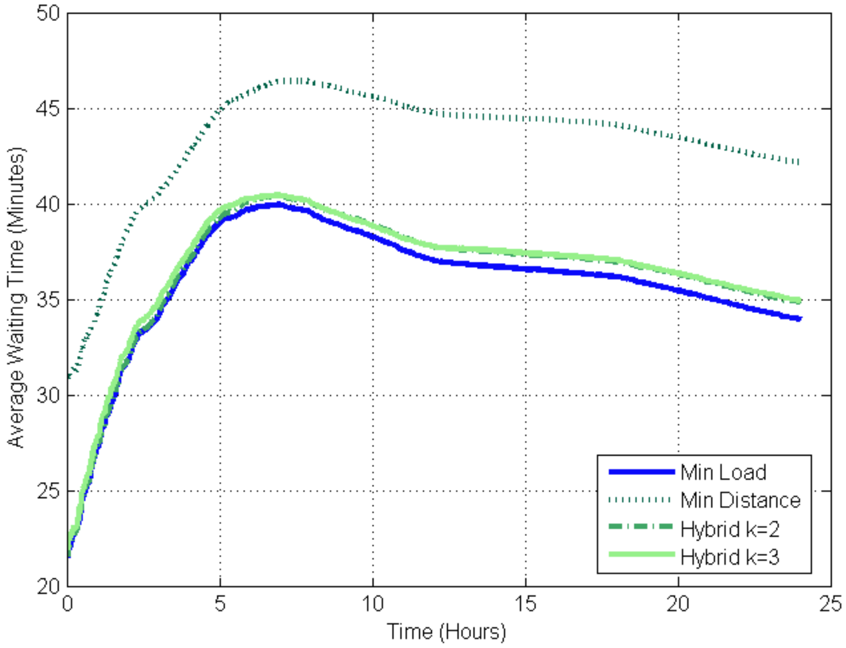


Figure 5.1. Average waiting time graph for the time-based simulation.

It can be observed that the Min Distance has the highest waiting time, because max ρ is high for minimum distance and this increases the service time. The Min Load is slightly better than the Hybrid algorithms, for the specified base λ value of 160 requests.

For all of the algorithms, it is possible to see the increase in the average waiting times during the initial 6 hours when the arrivals are too frequent.

For the metric success ratio the performance of the algorithms is also shown in Figure 5.2.

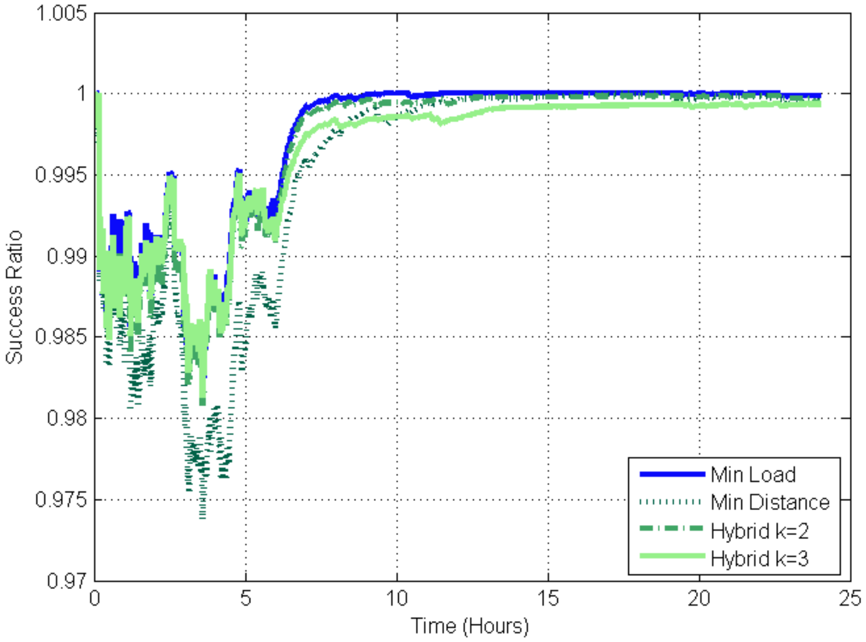


Figure 5.2. Success ratio graph for the time-based simulation.

We observe that the Min Distance has the lowest success ratio and the difference between the Min Distance and the Min Load increases dramatically for the case of a dense load (first 6 hours of the simulation). This means, in a panic state, the Min Distance fails to handle the load. The Min Load adapts better to such an increased load. After the 6th hour of the simulation with low arrival rates, all the algorithms approach to 1 in success ratio.

The Min Distance and the Hybrid algorithms exhibit close success ratios. However, the Hybrid with *k=3* has a lower success ratio than the Min Load and the Hybrid with *k=2* algorithms. The reason is that, as *k* gets larger, the algorithm becomes more the Min Distance-alike.

Finally, the performance of the algorithms with respect to maximum load ratio (max ρ, which is the maximum value of load-capacity ratio among all of the hospitals) is shown in Figure 5.3.

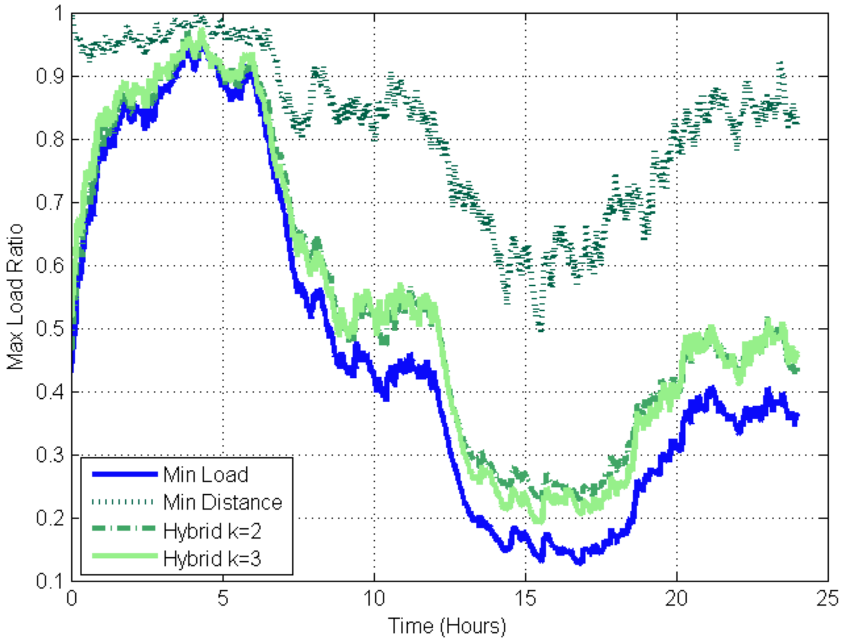


Figure 5.3. Maximum load ratio graph for the time-based simulation.

It is observed that the Min Distance has the highest max ρ, also getting so close to 1 when the arrival rate is high. The Min Load is the best in keeping the max ρ at its lowest value. The Hybrid algorithms are slightly worse than the Min Load. The Hybrid algorithms' ρ values are also very close to each other. As they behave both like the Min Distance and the Min Load, their results also tend to be between the values of those.

Moreover, it is possible to see the arrival density from the time scale that the first 6-hour period has the highest density of arrivals. The third 6-hour period has the least dense arrivals. The second and fourth periods are moderate. The arrival rate and the max ρ are proportional to each other.

Additionally, the histograms in Figure 5.4, 5.5, 5.6 and 5.7 show the fairness of the algorithms in giving service to the incoming requests.

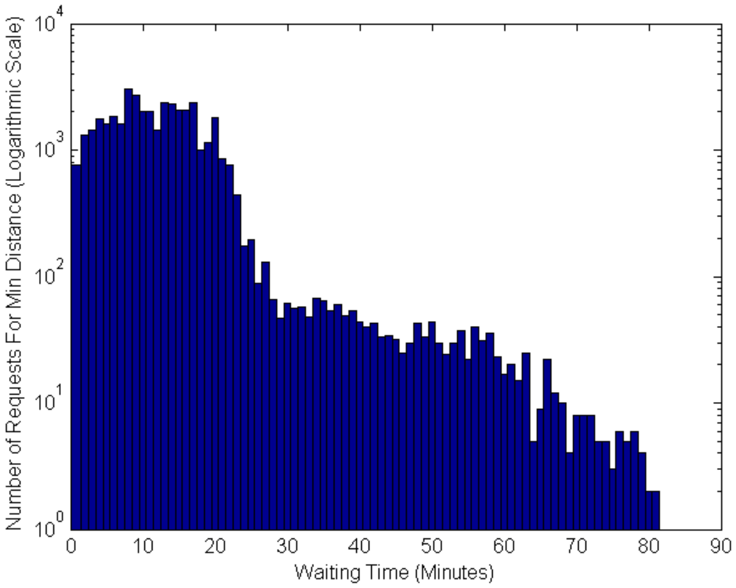


Figure 5.4. Number of Requests Distribution for Min Distance for the time-based simulation.

The Min Distance algorithm is more unfair, having waiting times up to about 80 minutes. The other algorithms have their maximum waiting time values about 65-70 minutes.

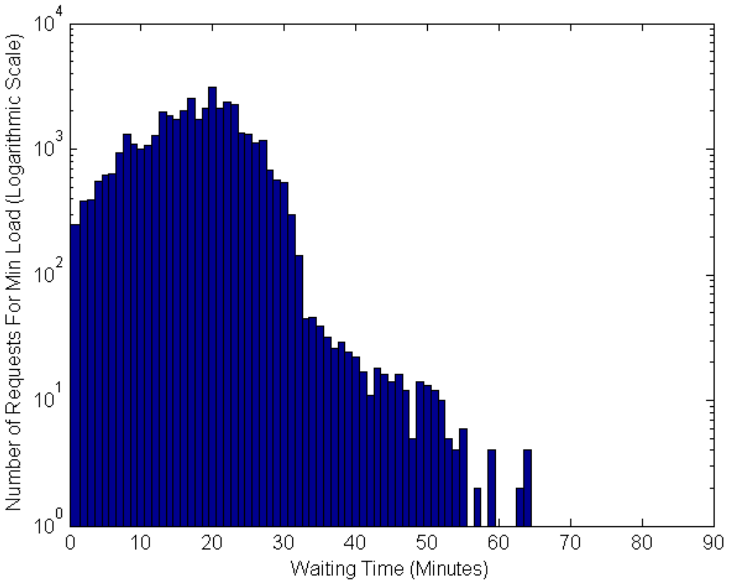


Figure 5.5. Number of Requests Distribution for Min Load for the time-based simulation.

Another aspect to observe is that, the Min Distance has more waiting time values closer to zero. The reason is that, it suffers less due to travel overhead.

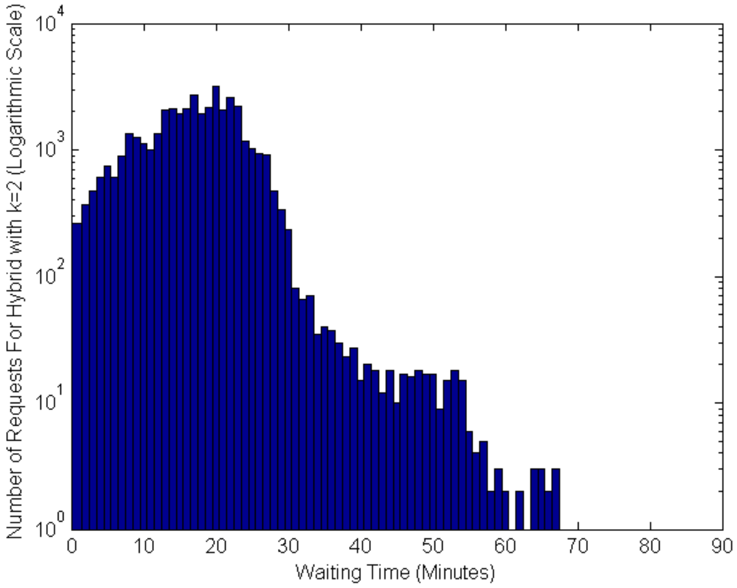


Figure 5.6. Number of Requests Distribution for Hybrid with k=2 for the time-based simulation.

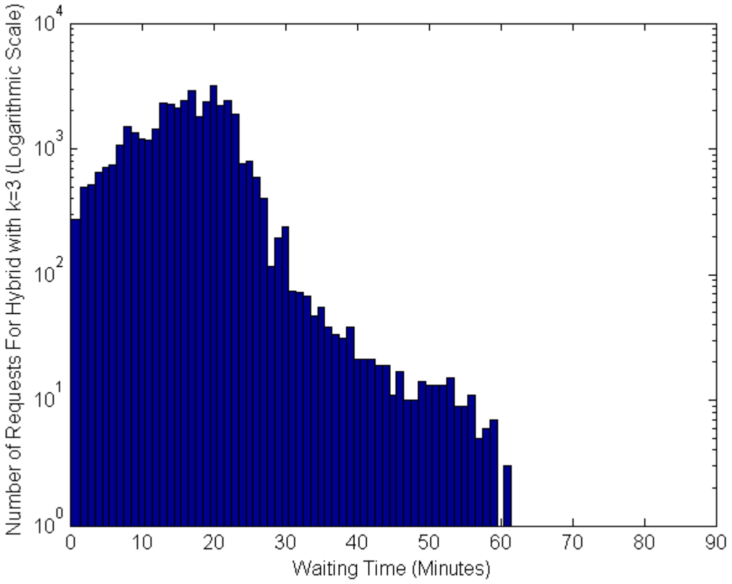


Figure 5.7. Number of Requests Distribution for Hybrid with k=3 for the time-based simulation.

In addition, as *k* increases, it is observed that the Hybrid schemes get more the Min Distance-alike, with the increase in the number requests which possess the highest waiting time.

5.2.2. Request Interarrival Time Analysis

The performance of the algorithms with respect to the metric average waiting time is shown in Figure 5.8.

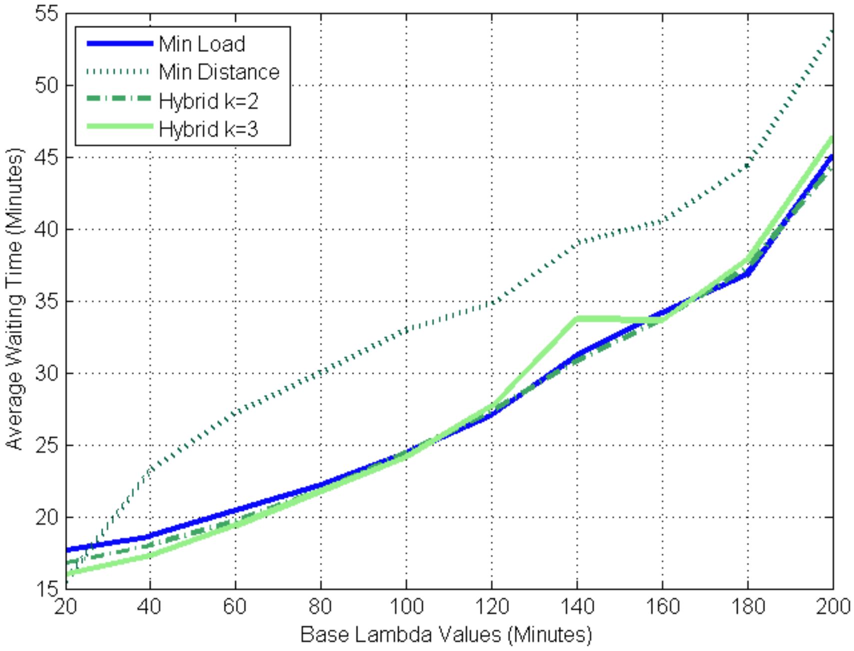


Figure 5.8. Average waiting time graph for the λ-based simulation.

It can be observed that with added service time, which is also affected by the load ratio of the hospital, the Min Distance is the worst in waiting time. It loses from the travel overhead. However, it gains from short service times caused by low max ρ. This way, the Min Load becomes better than the Min Distance when waiting times are considered.

Compared to the Min Distance, the Hybrid algorithms are better with low λ, because they gain from travel time. On the other hand, as λ increases, the Hybrid algorithms become more and more the Min Distance-alike. So, the Min Distance becomes a better choice with its lower max ρ, thus, with its lower service time. When high load is considered, the Min Load is better than the Hybrid with $k=3$. On the contrary, the Hybrid with $k=2$ is still better than the Min Distance.

For the metric success ratio the performance of the algorithms is shown in Figure 5.9 as well.

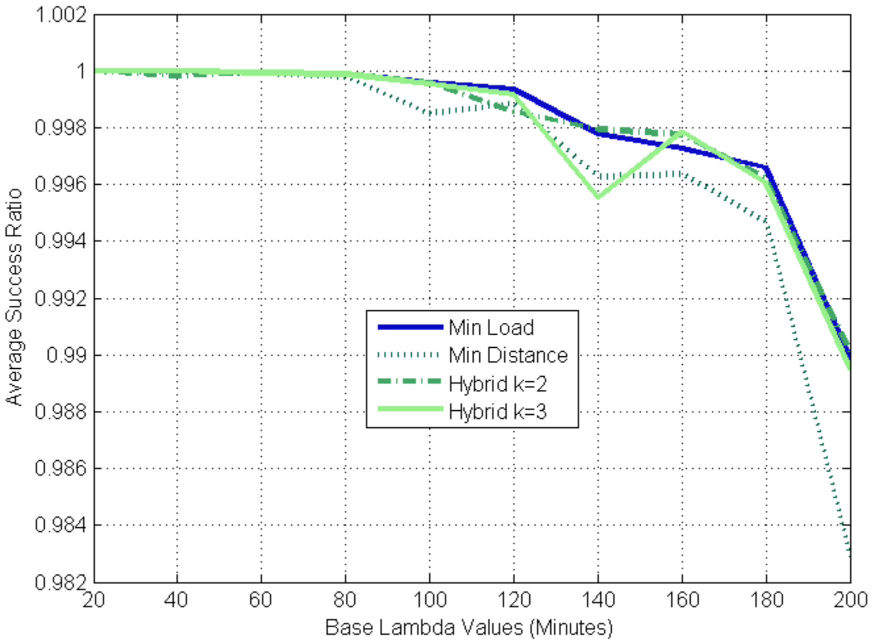


Figure 5.9. Average success ratio graph for the λ-based simulation.

We observe that the Min Distance is the worst in average success ratio, because it neglects balancing the load on the hospitals. This causes more and more of them to get full. As hospitals get full, newly arriving requests cannot be served and this lowers the success ratio.

The Min Load and the Hybrid with $k=2$ have close average success ratios for most of the λ values. The Hybrid with $k=3$ has a slightly worse average success ratio, because it is more similar to the Min Distance algorithm.

Lastly, the performance of the algorithms with respect to maximum load ratio is shown in Figure 5.10.

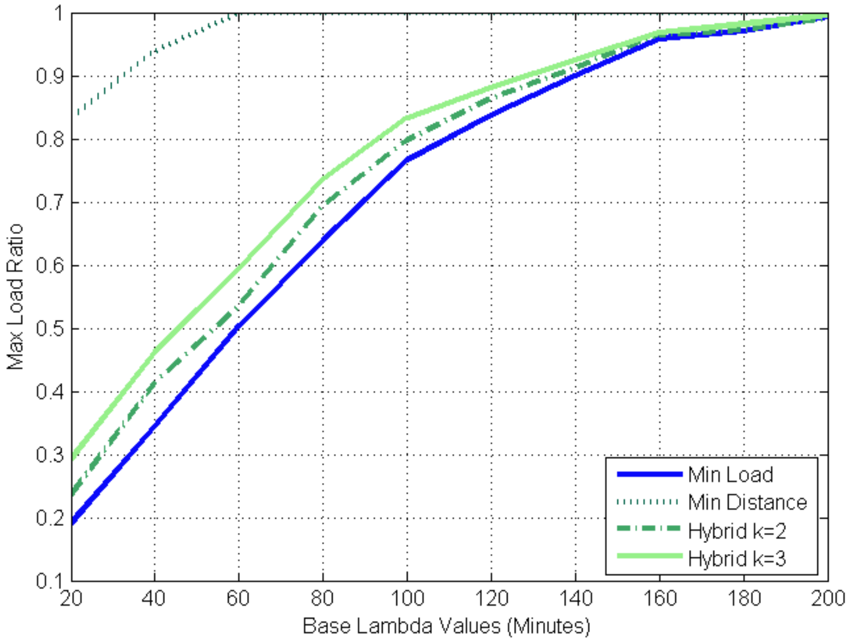


Figure 5.10. Maximum load ratio graph for the λ-based simulation.

It is observed that the Min Load is the best and the Min Distance is the worst with respect to max ρ, because the Min Load considers minimizing the max ρ while the Min Distance totally neglects it. The Min Distance reaches the maximum load when base λ is equal to just 60 arrivals.

For the Hybrid algorithms, as k gets larger, the algorithm maintains a higher max ρ since it gets more similar to the Min Distance algorithm.

6. CONCLUSION AND FUTURE DIRECTIONS

In this thesis, the issue of resource management in response to emergency and disaster situations is addressed. For the purpose, the system *Disaster Management Platform (DMP)* is represented. Within the system, different resource management algorithms are proposed by giving different levels of importance to load balancing and service time. The performance of the algorithms is evaluated with respect to waiting time, success ratio, and maximum load ratio.

The results show that giving more importance to load balancing gives better results in success ratio and maximum load ratio, as well as waiting time. In addition, as the arrival rate of requests (load) increases, balancing the load on resources gets more and more important. Consequently, the performance of the Min Load algorithm increases.

Under higher loads, the Hybrid algorithms can outperform both the Min Load and the Min Distance by combining features from both. On the contrary, the Min Load is generally the best in all metrics. Moreover, the Min Distance is the worst in all cases and in all metrics. Also, increasing k in the Hybrid algorithm gets the performance metrics of the algorithm closer to that of the Min Distance.

The next step would be deploying the DMP system in a real environment and running a real drill. Moreover, the algorithms should be tested with respect to higher load for further comparison.

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