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Message Framework for Disaster Management: An Application Model for Mines

A. Baloğlu, A. Çınar

Abstract**—**Different tools and technologies were implemented for Crisis Response and Management (CRM) which is generally using available network infrastructure for information exchange. Depending on type of disaster or crisis, network infrastructure could be affected and it could not be able to provide reliable connectivity. Thus any tool or technology that depends on the connectivity could not be able to fulfill its functionalities. As a solution, a new message exchange framework has been developed. Framework provides offline/online information exchange platform for CRM Information Systems (CRMIS) and it uses XML compression and packet prioritization algorithms and is based on open source web technologies. By introducing offline capabilities to the web technologies, framework will be able to perform message exchange on unreliable networks. The experiments done on the simulation environment provide promising results on low bandwidth networks (56kbps and 28.8 kbps) with up to 50% packet loss and the solution is to successfully transfer all the information on these low quality networks where the traditional 2 and 3 tier applications failed.

Keywords**—**Crisis Response and Management, XML Messaging, Web Services, XML compression, Mining.

I. Introduction

A disaster is the tragedy of a natural or human-made hazard (a hazard is a situation which poses a level of threat to life, health, property, or environment) that negatively affects society or environment.Unfortunately disasters are inevitable and they can take many lives and cause big economic losses. Many private and public organizations are established to manage and minimize the effects of the disasters, and they are actively putting their efforts to manage the risks and assist victims of the disaster incidents.

Coordination of the disaster response is an important activity for saving lives and reducing the effects of the incident. In order to regulate this effort different regulations and methods have been generated. For example in Turkey the disaster response activities are regulated by "Disaster Law" [1] and according to this law the main responsible body that should coordinate the disaster relief operations is the highest civil authority such as Provincial Disaster and Emergency Directorate which belongs to Istanbul Governorship [2]. In order to assist their operations, this directorate uses "Disaster Information System" [3] where the system provides key logistic information about important and critical sources (blood, medication and etc.), location of important buildings, topographical information and etc.

In the Global Disaster Information Network Conference held in 2001, an overview study that was carried out on National Disaster Management Information systems in Asia orPacific region was presented [4]. This study shows that many developed systems are mainly aiming at the post-disaster planning and coordination activities. Also they provide similar information databases as in the Istanbul Governorship's Disaster Information System.

In general our study indicates that these systems are depending on the availability of healthy network connectivity between server and client applications to exchange data. However, depending on type of disaster or crisis, network infrastructure could be affected and it could not be able to provide reliable connectivity. By introducing offline capabilities to the web technologies and providing message prioritization schema, our study proposes a methodology which could work on low quality networks. Details about technical implementation of the solution are outside the scope of this paper as our work is not finalized. In this paper we will summarize our model and initial test results of the first prototype.

II. Related Work

In our study we focus on creating reliable information exchange framework by employing different techniques and technologies. Firstly, in order to establish messaging standard, Extensible Markup Language (XML) [5]message-basedschema is implemented. Even though today XML is one of the most commonly used standard for exchanging data and pretty much all platforms support the XML formatted messages, and as it is designed as a text markup language, it also brings an overhead to the message. The additional tags and text conversion increase the size of the message and cause this overhead. In order to overcome this overhead problem, there are several studies that have been carried out on XML message compression methods and this project will benefit from these methods.

Comprehensive studies on XML compression methods and networking performances were carried out by [6] and [7]. In these studies different compression methods and their performance were evaluated. Another study which uses compression in order to reduce network overload was carried out by [8]. Experimental results provided in this paper indicates that the usage of compression algorithms indeed provide better network performance because the transfer message sizes are reduced further more by compression

A. Baloğlu is now with the Computer Engineering Department, University of Marmara,İstanbul,Turkey (phone: +90 542 3032208; e-mail: arzu.baloglu@marmara.edu.tr and karzubaloglu@gmail.com).

A. Çınar is now with the Department of Business Administration, University of Marmara, İstanbul,Turkey (phone: +90 5325115558 email: acinar@marmara.edu.tr).

method. As the study offers a middleware solution, the complexity of the system is isolated from applications.

The web services allow sharing the operational functionality with a standard interface which does not require sharing the application logic. However, because web services implement XML base message exchange over internet protocol, they also inherit overhead problem of XML. In order to provide a solution to resolve overhead issues related to the web services, different studies have been carried out. In our project we also use the idea of implementing middleware for overcoming network issues; however compressing the message could not provide better information exchange over unreliable networks. So we improve the idea by introducing message framing, frame control and message prioritization.

In order to get best usage of limited networking capability, prioritization schema has to be implemented for avoiding huge amount of low priority data which occupies the resources while high priority data waiting for transfer slot. In order to provide reliable priority schema, the variably weighted round robin (VWRR) queuing algorithm, which is originally implemented on core IP routers [9], is selected as our priority schema. In this technique, prioritization of the messages is done by adaptive weighting function, which calculates priorities according to average lengths of the packages and size of waiting queue. The test results provided in this study indicates that the proposed algorithm provides fairness while it guarantees bandwidth over IP Networks. VWRR algorithm is selected for handling priority queues in this project.

At the current stage of the project, the framework is implemented without prioritization schema on the simulation environment created on VMware [10] environment. On the simulation, the success of this information exchange framework is tested for different network conditions where bandwidth varies between 28.8 Kbps and 1 Gbps, and network quality varies between 0% packet losses and 80% packet loses. These network conditions are used for simulating the disaster environments where networking infrastructure is affected and does not provide persistent and reliable connectivity. At this stage, initial prototype provides promising results where it is able to transfer information over low quality and low bandwidth networks where standard way of data transfers fails.

III. Framework Architecture

Depending on many factors such as environment, disaster type, size of the disaster and etc., it is quite possible that the communication infrastructure could not support reliable networking. In such cases two key functionalities are expected from any information technology solution; offline data collection and best possible information exchange. Our project proposes a solution framework equipped with different functionalities in order to ensure reliable information exchange between disaster response teams and coordination centers over unreliable network. The functionalities offered in the framework are:

1) Offline data collection capability.
2) Generic client and server interface for external applications, where external applications use this interfaces for their information exchange needs between server and client sides. In current implementation, our study focuses on supporting applications which uses open database management systems with SQL support.
3) Web Service interface for supporting platform independence and sharing operational functionality.
4) XML based messaging schema, which employs data compression and message prioritization.
5) Verification and validation of the transferred data with MD5 checksum.

The framework uses control databases on both client and server side (Fig. 1). These databases store configuration, system information and priority messaging queues. These queues are used for storing packaged messages coming from external disaster response system. Also by using these control databases the framework gain offline data collection capability.

The generic XML format (Fig. 2) created for receiving message from external applications is used for crisis response operations. In the format, the DEF attribute contains the name of the table located on the external database. The COLUMNS element contains the comma separated column names of the table. The DATATYPES element contains comma separated data type information of each column listed in COLUMNS element. Here data types should be given as ODBC SQL data type format [11]. The ROW elements contain the column values of the each row. The ROW elements are also child elements, which are basically columns, listed in COLUMNS element and each column name in this list is a child element name of the ROW element.

The hearth of the framework is two engines that are implemented on both client and server side. The overall information exchange between each side is regulated by these engines (Fig. 3). On the client side the framework engine receives the client data from external application in the predefined XML messaging format. The Message Packaging Control (MPC) component of the engine compresses and splits the received data into standard size messages. These packed messages will be stored in the control database. In this process, the MD5 hash of the original message also stored in the control database where this hash value will be used for data verification at the destination when the whole package is transferred.

The XCMILL, GZIP, BZIP and XMLPPM [6], [7] compression methods are implemented on the MPC component and depending on configuration selection MPC employs one of these methods for compressing the XML formatted message. Then it splits the resulting compressed message into small standard sized packages. Initially all compressed messages are split into 16KB packages and during transfer process if the transfer of the package fails more than threshold values set for the client, the package will be split into half (until package size reach to 1KB).

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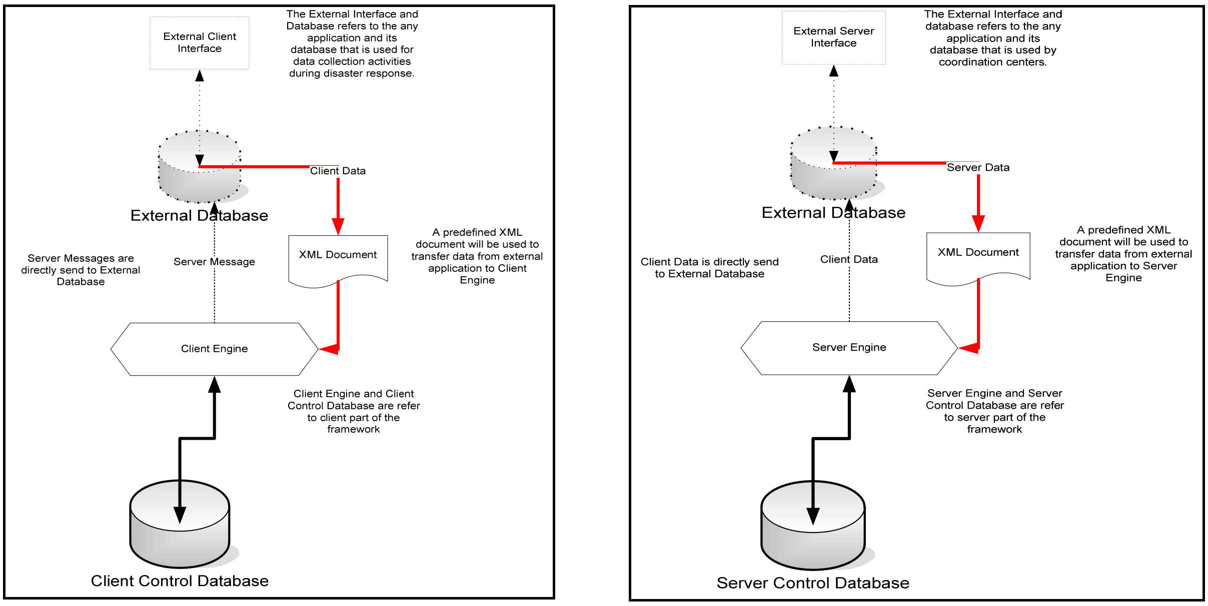

Fig. 1 Message Flow (Client-Server)

```
<?xml version="1.0" encoding="ISO-8859-1"? >
<BODY>
<DEF></DEF>
<COLUMNS></COLUMNS>
  <DATATYPES></ DATATYPES>
<ROW><COLUMN NAME></COLUMN NAME> ... </ROW>
  <ROW>... </ROW>
  <ROW>... </ROW>
                ...
</BODY>
```

Fig. 2 XML Format

The main differences between server and client engines are the Priority Messaging Control (PMC) component at client side and Listener component at the server side. As long as PMC component detects network connectivity between client and server, it tries its best to transfer the stored messages. PMC also performs package splits during this transfer process. The second task of the PMC is to adjust the priority queues by using VWRR algorithm. The final task of the PMC is to retrieve the messages waiting at the server site for its client.

On the other hand, the Listener component at the server side passively waits for client PMC components' requests. Listener stores received packages into control database and when it detects that all packages belong to a received message, it reconstructs the original message by joining packages together and decompresses the message. During this process Listener also verifies the message by using MD5 hash that came with the packages. Another role of the Listener is to deliver the server messages to the clients. When PMC requests the delivery of the server message, Listener delivers it in the same way that PMC delivers the client messages. Again at the server side, these server messages are packed by MPC and stored into the control database.

IV. Customization of the Model for Mine Emergency Communication Technologies

A. What is the Health and Safety Problems of the Related Miners?

In the event of an underground emergency, mine workers should have a way to communicate with and be tracked by the people on the surface. It requires mines to have wireless communications and electronic tracking systems in underground coal mines. The intent is to provide communications and location information between surface personnel and underground workers. The systems should be survivable and remain operational following a disaster to aid in self-escape and rescue operations.

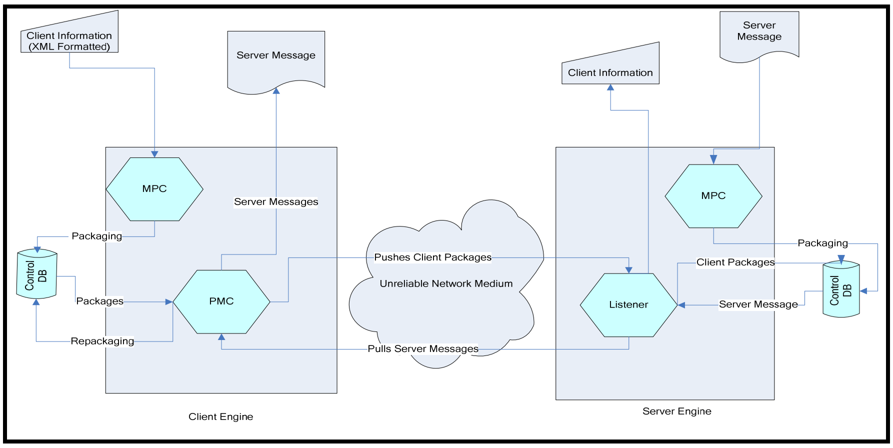

Fig. 3 Client and Server Engines

B. What is the Extent of the Problem?

As a result of the MINER Act, all underground coal mines now have some form of wireless communications and tracking (CT) systems installed. However, because every radio has a limited transmission range, all CT technologies require some amount of underground infrastructure to transfer messages and information between the working section and the surface. The infrastructure could be damaged by a disaster, rendering the CT systems inoperable. Therefore, mine operators, regulators, and CT manufacturers need a way to assess the survivability of CT systems quickly and effectively. Furthermore, this assessment needs to account for the specific mine layout, the type of CT equipment, the installation configuration, and the disaster definition (location, type, extent, forces, temperatures, and debris) [12].

Some Technologies have been developed to eliminate fatal accidents, to minimize health hazards and to promote improved safety and health conditions in mines. Most research of indoor localization systems have been based on the use short-range signals, such as Wi-Fi, Bluetooth, ultrasound, infrared or RFID.

There are some equipment to allow underground personnel to talk to each other and to the surface such as Wired Equipment, Fiber-optic Equipment and RF Equipment. They are shown in the following table [13]:

TABLE I
MINE EMERGENCY COMMUNICATION EQUIPMENTS

The Type of Equipment	Contained Equipment
Wired Equipment	Telephones
	Public Address
	Loudspeaker
Fiber-optic Equipment	Ethernet VoIP
	Multiplexed Baseband Audio
RFEquipment	Antenna
	Leaky Feeder
	Node (Mesh)

V. CONCLUSION

In the current stage of our study, we established a prototype application which implements control database and client/server engine without prioritization schema. Then we created a test environment where unreliable network conditions were simulated by using virtual environment.

The test environment was implemented by using VMware Workstation ® (http://www.vmware.com/products/ws/). In the test environment two virtual computers were teamed for testing the solution. Each guest system had Windows 2000 Pro OS, 8GB disk space, 256MB Memory and 1 CPU. The host system had Windows XP Pro OS, 100GB disk space, 2GB memory and dual core 1.3 Ghz Intel Centrino® vPro CPU.

As a baseline software Apache 2.2.11, MYSQL 5.1 and PHP 5.2.9 were installed to both guest systems. The XCMILL, GZIP, BZIP and XMLPPM compression methods [6],[7] were used for this test. The compression tools were obtained as open source software from following reference sites.

When we simulated information exchange between client and server sides with random files where average compression ratio observed as 48.7%, we obtained results shown on Table II.

These results show that the MPC implementation allows successful transmission of the messages on unreliable networking conditions. In the remaining part of the study we will focus on finalizing the PMC and reducing the overhead introduced by MPC.

On the other hand, this model can be customized for Mine Industry in an effective manner. Wepropose the similar method and technology and so they can work on this model as a future plan. Especially it could be a very useful tool for our mines and miners in our country. We have felt very upset when we experienced "Soma Disaster" recently and more than 301 miners have died in this mine disaster.

It has occurred when an explosion sent carbon monoxide gas into the mine's tunnels while 787 miners were underground.

That is why; we extremely propose some similar methods for mine industry to communicate for help. And we hope some researchers will be able to focus on this matter in order to develop a custom model.

TABLE II
TRANSMISSION TEST

Network Setup	Without Framework (millisecond)	XCMILL (millisecond)	GZIP (millisecond)	XMILL-PPM (millisecond)	BZIP (millisecond)
1Gbps	2203	12066	9368.5	7100	8777.5
56kbs no data loss	211500	261671.5	261766.5	255778.5	261017.5
56kbs 10% data loss	380344	314001.5	360878.5	291419	364892
56 kbps 25% data loss	Unsuccessful	3512410.5	3526450	3339351.5	3515044
56kbs 50%data loss	Unsuccessful	33376906.5	33553492	31767979	33376951
28.8kbs no data loss	499656	570698	564716	543129	571910
28.8kbs 10% data loss	1626469	1337146.5	1331173.486	1276329.5	1327002.5
28.8 kbps 25%data loss	Unsuccessful	5540293	5232466	5039862	5252662.5
28.8kbs 50%data loss	Unsuccessful	50759879	51001894	48391025.5	50721063.5

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Dr. Baloglu, completed her undergraduate at Technical University of Istanbul, her MBA in production management at University of Istanbul, and her PhD in Information Technology at University of Istanbul. She has experience of 15 years in production and technology management. She worked for various plants including manufacturing, service and consulting companies as middle or top manager. For instance, Ernst and Young Consulting Turkey is one of the companies, where she added important values within 5 years. Also she worked in SAP Business for a long time and managed various SAP/ERP projects in Turkey and also abroad. Now she is serving in ERP, CRM and e-business categories as senior consultant and lecturing at various universities. She gave the lectures and courses in the Universities of Bilgi, Işık and Yeditepe. Additional to these she is sometimes giving conference seminars and company trainings in her expertise areas. Dr. Baloglu has about 15 professional and academic papers, published in various technology magazines and books. And she currently works for Marmara University - Dept. of Business Administration under title of Asst. Prof and also teaches the some courses in Yeditepe University as part time lecturer.

Dr. Çınar, completed her undergraduate at Istanbul University. She also earned MBA and PhD inQuatitative Methods at the mentioned university. After graduation she had worked for a computer center in İstanbul University for 3 years then, being a lecturer, she started to work in academic area and passed Vocational High Schools of Social and also Technical Sciences respectively in İstanbul University and teached some courses with various subject such as algorithm, introduction to computer and also software development. She currently works for Marmara University inthethe Sub-Department of Quantitative Methodsof the Department of Business Administration under the title of Asst. Prof and she teaches some courses such as Decision Theory, Game Theory and Data Mining.