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DESIGN, VALIDATION, SIMULATION AND PARAMETRIC EVALUATION OF A FAULT TOLERANT NETWORK TRADING SYSTEM BY USING MOBILE AGENT

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Abstract- Ever since its emergence, Mobile Agent (MA) technology has been advocated to revolutionize the way, we go shopping on the Internet. This paper proposes a network trading system named BestDeal. It allows launching personalized mobile agent to autonomously gather information about products needed to be bought on behalf of user. Mobile agent can be programmed to find the best deal based on the criteria specified and can purchase the product on behalf of the user. While being a promising paradigm, many intricate problems need to be solved to make this vision a reality. Hierarchical Fault Tolerance Protocol (HFTP) for MA is used to make BestDeal fault tolerant i.e. a user, who launches the MA, receives it back with correct result within time limit in spite of hardware and software failures such as link failure, host failure, or crash of MA or mobile agent system (MAS).
Proposed system has been modeled by using a well known Colored Petri Net (CPN) tool. Designed model has been analyzed and validated by using validation tools such as state space report and module checking. Parameter based performance analysis of fault tolerant BestDeal system has been done by using experimental simulations results.
Keywords- Mobile Agen, Mobile Agent System, Fault Tolerance, Colored Petri Ne, Hierarchical Fault Tolerance Protocol, Network Trading

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Introduction To Network Trading System

Although the network trading [18] is different from the traditional trading but the basic functions of trading remain unchanged where consumer wants to buy product and services while suppliers supply them. BestDeal is a network trading system where consumer (buyer) is represented by shopping mobile agent and suppliers are represented by selling agents. A buyer interested in buying a product launches a shopping mobile agent to retrieve information of products in an electronic marketplace [19] by specifying his buying criteria and provides it with a list of supplier's sites to visit. An electronic marketplace consists of suppliers that sell products on the network. Each supplier maintains a huge products catalog and supports some basic services to access and operate on product catalogs which are stored as XML [14] files.
Shopping mobile agent completes the transaction based on the given criteria by specified time limit. A buyer that programs the agent for buying certain product may specify his criterion as obtaining the lowest possible price for that product. The buyer wishes to obtain prices from various online shops, programs the agent to visit different servers and querying them for the price of the product. The buyer goes offline after launching the agent. The agent visits each host on its itinerary, collecting prices from each host, and returns to the buyer with the best offers. Now the buyer can launch the purchase agent or abort the query. BestDeal system recommends XML documents and code to avoid conversion and to improve efficiency of the system in terms of time and computation. Shopping criteria, criteria evaluation logic and product catalogue are implemented as XML document.
In BestDeal system two types of sites are maintained Buyer's Site and Supplier's Site. Buyer's site is responsible for accepting the buyer request and launching shopping agents. At suppliers sites shopping agent gets offer and update the data. Since two sites have different roles to play and to maintain different types of data and services, the components at these sites are different.

Components At Buyer's Site (See Fig-1)

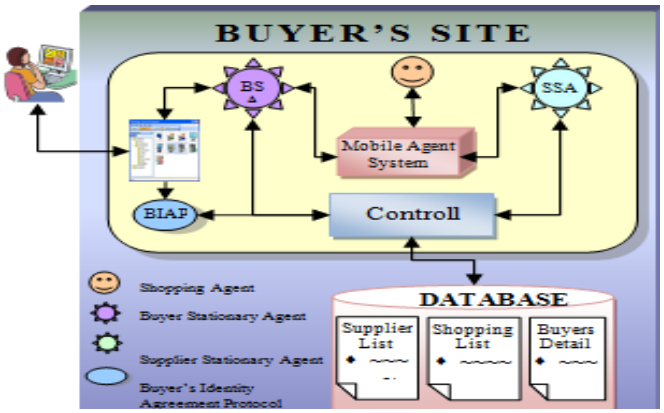

Fig.1- BestDeal architecture at Buyer's Site

Human Buyers

A person, interested to get the best deal offered over the Internet for specified products and is not interested in searching for information all over the net. Each buyer is required to get registered and uniquely identified in the trading environment.

Buyer's Identity Agreement Protocol (BIAP)

Buyer's agreement protocol [14] accepts unique user name and password to register a buyer. It maintains the database of the registered buyers. Password is used to protect unauthorized access of user's account by someone else.

Buyer's Graphical User Interface (BGUI)

It is the interface between the buyer and Buyer Stationary Agent, responsible to create SA. BGUI allows the buyer to register, submit shopping list and to specify shopping criteria. Best deal obtained by SA is also shown through BGUI.

Shopping List

In shopping list, product may be specified by its name, category, brand name etc., but BestDeal assumes that there exist a universally accepted coding technique for products and product is specified by numerical code and characterize by parameters such as price, brand, model etc.

Mobile Agent System

BestDeal requires a MAS to provide execution environment for Mobile Shopping Agent. Any existing MAS which provides support for agent creation, arrival, dispatch and agent management may be used.

Buyer Stationary Agent (BSA)

It creates one SA for each product in the shopping list. It is responsible for managing resources and service at the buyer's end and for calling MAS routines.

Shopping Mobile Agents (SMA)

A SMA is launched for each product in the shopping list, The SMA is provided with a list of supplier's site to visit, the product code, characterizing parameters, shopping criteria and criteria evaluation logic.

Supplier Stationary Agent (SSA)

SSA is responsible to get suppliers detail. It is made aware of the suppliers identity through advertisements, mobile sales agent sent by suppliers or by launching an agent to get list of available online suppliers before launching SA.

Buyer's Database

Buyer's site maintains the database of registered buyers and supplier's site addresses across the network. Buyer's user name with the site address identifies it in the Virtual Market [9].

Database Controller

Controller is a routine to access buyer's database on request of other stationary and shopping agents.

Compnents At Supplier's Site (See Fig-2)

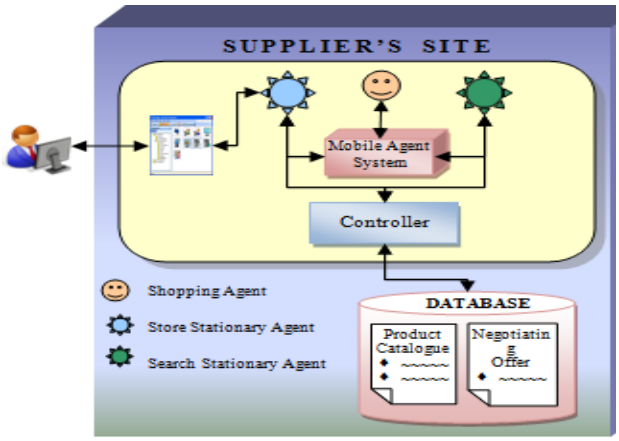

Fig. 2- BestDeal architecture at Supplier's Site

Store Stationary Agent (TSA)

Store Stationary Agent receives the shopping agent and verifies its identity. It provides it the product catalogue and offer. It also stores the list of all SAs visit the site and product querying by them to negotiate the buyer latter.

Search Stationary Agent (CSA)

Search stationary Agent, searches the product in product catalogue according to the characterizing parameter and product evaluation logic. It then filters all matched offer.

Mobile Agent System

Each supplier site must also install the same MAS as Buyer's site to host, execute and dispatch the SA.

Supplier's Database

Supplier's site maintains the product catalogue, valid offers, buyer's identity as well as list of all shopping agent visited the site together with the product detail and offer.

Controller (supplier)

\It is a software routine to maintain the supplier database. It access database at the request of other stationary and shopping agent.

Possible Faults in BestDeal

In BestDeal system, once the shopping agent is created and injected to the network, launching site has no control on its execution. Shopping agent may fail due to failure of any of the components of the system. We have identified four kinds of faults in BestDeal system.

- Failure of Shopping Agent itself.
- Failure of MAS or any of BestDeal components at the supplier site hosting the Agent.
- Failure of supplier Host.
- Link failure during migration.

Due to any of these faults [3][12] buyer will not get the correct result on time. The "shopping agent failure" can be handled at programming level by providing exception handling code for all kinds of faults that may occur during execution.

HFTP for Best Deal

All the faults mentioned above can be tolerated by incorporating the components of Hierarchical Fault Tolerance Protocol (HFTP) with MAS. HFTP has been motivated by our previous work [5][6] as well as several prior researches done in the area of agent fault tolerance. These include concept of rear guards [2] based on fault detection and recovery and idea of masking the fault by grouping the hosts [15] instead of replication [7], [17]. Our approach is also inspired by 3-layred monitoring system [13] and check-pointing approach [16] to insure the transaction atomicity of the MA.

On each supplier's network, supplier database must be stored at the shared storage space where storage space is assumed to be fault free. Some hosts together with the supplier host must be authorised to access the database. All these hosts together with the supplier host will form a group within a network. Each host of the group must install all the components of BestDeal and can execute the shopping agent and provide it the best deal. In spite of the BestDeal components, HFTP components such as PDS, LDS and GDS are also installed on Router of the supplier's site as well as on each hosts of the supplier's group. One host in the group works as In-charge of the group. State of shopping Agent is checkponted after every successful transaction and whenever required. Checkpoint data is used to recreate the agent in case of failure. Checkpointing is also done in the shared storage space. We are here showing that HFTP is a generalized protocol which can make any existing MAS Fault tolerant by installing all its components and satisfying its requirements.

CPN Model for BestDeal

CPNs are a powerful modeling technique for complex systems [1][8].CPNs combine state and action into a single diagram through the use of tokens of various colors which reside in places. Tokens move from one place to another through transitions. Transitions allow tokens to pass if all input arcs are enabled. We have modeled the BestDeal system by using CPN [10][11]. Once the model was constructed, we used several simulation runs to check its correctness. Initial simulation runs used combinations of manual binding, play and fast-forward tool. Also the proper firing times of timed-transitions were noted. Once this procedure was followed for several runs, simulation using Markup Language code was done to generate concise simulation reports. Various data collector monitors were used to gather statistics and to check properties of CP Net.

Experimental Setup

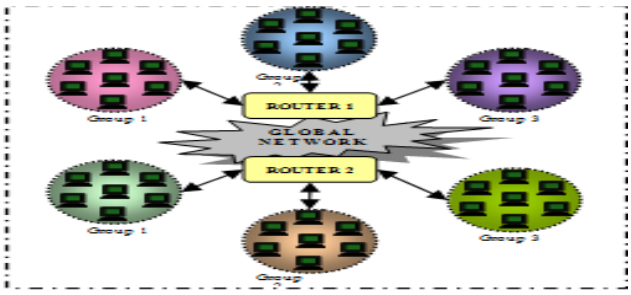

Fig. 3- Exprimental Setup for BestDeal

In order to test the model for its correctness as well as to generate data for analysis, the experimental setup shown in Figure-3 has been used.

There are two networks connected via Router1 and Router2. There are three groups on each network. Groups at Network-1 are *11, 12, 13* and at Network two are *21, 22, 23.* Each group has seven hosts, each host is uniquely identified e.g., 123 is host 3 of group 2 at network 1. BestDeal system with HFTP components is installed on each host of the network. Global Group Table and Log Tables are maintained at the Router. Agent Table, failed host list and Checkpoint table are maintained for each group. Host, MAS, Shopping agent or link may fail. Their failure rate is set manually. Failed host & MAS recover automatically. The failed host list is modified accordingly. The link between the routers may also fail.

Supplier: Supp. List at each hosts is -[11,12,13,21,22,23]

Offer List: Offer is the pair of Product code and Cost.

Table 1- Product Offer List Available Suppliers Sites

Supp.	Product Code									Best
Code	1	2	3	4	5	6	7	8	9	Deal
11	110	200	300	X	X	600	170	800	900	1,7
12	120	120	X	380	520	580	X	780	800	2
13	X	250	130	X	550	650	750	180	950	3,8
21	180	280	380	140	X	X	780	880	980	4
22	X	190	X	390	150	590	X	790	190	5,9
23	X	250	350	450	550	160	X	X	950	6

Parameters for Performance Analysis

Timed CPN has been used to model fault tolerant BestDeal. Before starting the simulation, some parameters are required to be assumed while some are generated randomly or calculated during simulation. Here we assign values to some of the time based parameters before simulation starts. The assignment is based on the assumption that packet transmission time is fixed from any source to any destination; it is independent of place, time or load of network. The MA takes constant time to execute on any host.

Transmission time for MA = 200 time units
Transmission time for Ack. = 100 time units
Logging (Arrival/Departure) time= 50 time units
Host assignment for In-charge = 50 time units
Execution Time for MA/host = 450 time units
Recovery time for Mobile Agent = 50 time units
Time to Checkpoint data and state= 100 time units

Acknowledgement, Check-pointing and recovery of Host and MAs are done during MA execution, so these do not get added to the trip time of the MA.

To conduct the experiment, following data are set manually–

Buyer at Network 1 with Shopping List- [1,3,5,7,9]
Buyer at Network 2 with Shopping List - [2,4,6,8]
Supplier list for each product is - [21,22,23,11,12,13]
For simulation Agent identity - Product Code * 10

Model Validation and Results

Once the model was constructed, several simulation runs were used to check its correctness. Initial simulation runs used a combination of manual binding, play and fast-forward tool. Also the firing times of timed-transitions were noted. Once this procedure was followed for several runs, simulation using Markup Language code was done to generate concise simulation reports. Various data collector monitors were also used to gather statistics and to check

properties of CP Net.

Table 2- Details Of Shopping Mobile Agent Launched

Suppliers Address to be visited by SMA	Buyer's Address	Agent id	Supplier Address	Best Deal
Shopping Agent at Network -1				
21, 22, 23, 11, 12, 13, 11	111	11	99	9999
21, 22, 23, 11, 12, 13, 11	113	19	99	9999
21, 22, 23, 11, 12, 13, 12	125	15	99	9999
21, 22, 23, 11, 12, 13, 13	134	13	99	9999
21, 22, 23, 11, 12, 13, 13	135	17	99	9999
Shopping Agent at Network -2				
21,22,23,11,12,13,21	215	18	99	9999
21,22,23,11,12,13,22	223	14	99	9999
21,22,23,11,12,13,23	235	12	99	9999
21,22,23,11,12,13,23	237	16	99	9999

Result in a fault free environment is shown in Table-3

Table 3- Result Brought By The Shopping Agent

Buyer's Address	Suppliers' Site Visited by the Shopping Mobile Agents	Agent id	Supplier's Code	Best Offer
Shopping Agents at Network – 1				
134	13,42,16,22,72,33,11,10,00,000	13	13	130
113	11,32,17,22,52,34,11,50,00,000	19	22	190
111	11,12,15,22,42,35,11,10,00,000	11	11	110
125	12,52,16,22,62,36,11,30,00,000	15	22	150
135	13,52,17,22,62,32,11,10,00,000	17	11	170
Shopping Agents at Network – 1				
215	21,52,14,22,12,31,11,10,00,000	18	13	180
223	22,32,11,22,32,31,11,20,00,000	14	21	140
237	23,72,12,22,72,32,11,40,00,000	16	23	160
235	23,52,13,22,22,32,11,10,00,000	12	12	120

The last entry is the trip. Each SA visits the supplier list in static order and brings the best deal for the product.

Conclusion

Simulation were conducted by using different failure probability for MA, Hosts and Network and repeated hundred times. Each simulation was repeated hundred times. Their minimum, average and maximum values are used to plot the graph. It has been observed that all faults were tolerated by the protocol. Performance is measured in terms of execution steps as well as execution time of the simulation.

Figure 4 and 5 shows the performance in presence of host failure. MA survives even if failure rate is more than 80% however for higher failure rate performance degraded significantly. In reality host failure is not common so for rare failure MA survives without degrading the performance. Figure 6 and 7 shows performance in presence of MAS failure. This fault is also gets tolerated always without lowering the performance for lower failure rate. Figure 8 and 9 shows the performance in presence of link failure during migration. Rear guard based witness agent approach not only ensures the survivability of MA in presence of link failure but also achieve the tolerance without lowering the performance significantly. For higher failure rate performance degraded significantly. Our protocol improves agent survivability in presence of mentioned faults without lowering the performance significantly. However improvement comes at the expense of time, space, network traffic and reliable components as storage and router.

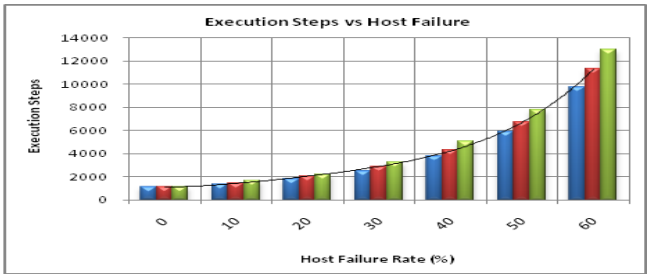

Fig. 4- Performance in terms of execution steps for Host failure

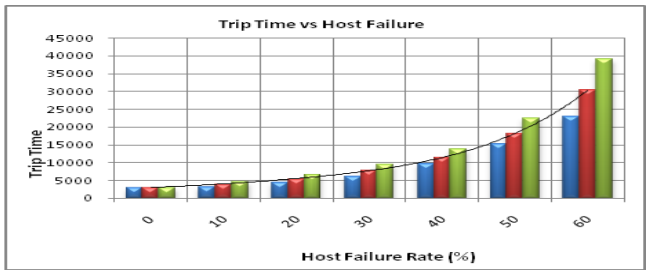

Fig 5- Performance in terms of trip time for Host failure

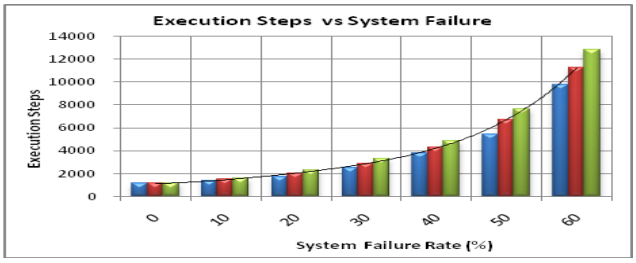

Fig 6- Performance in terms of execution steps for System failure

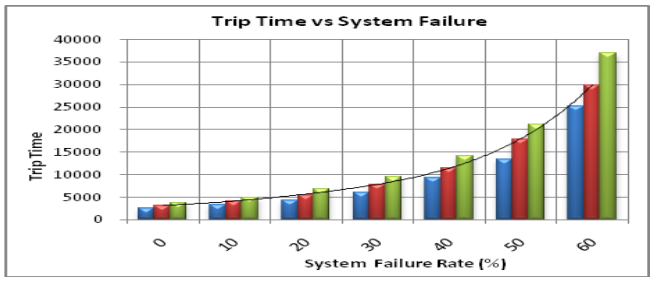

Fig 7- Performance in terms of trip time for System failure

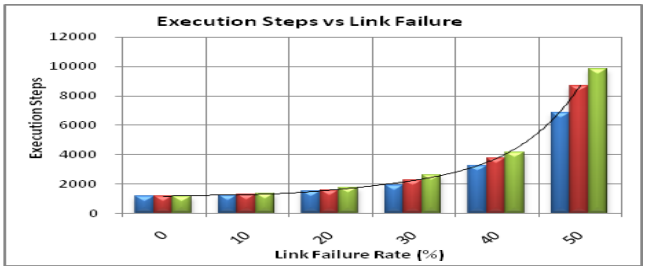

Fig 8- Performance in terms of execution steps for Link failure

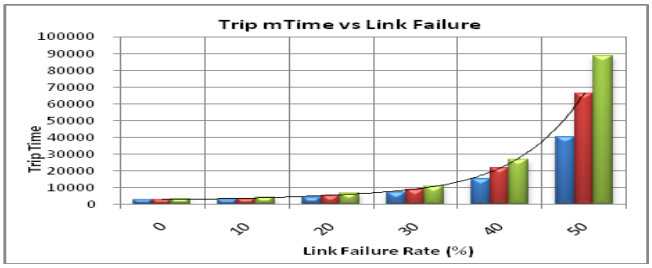

Fig 9- Performance in terms of trip time for Link failure

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