Full Paper

AN OPTIMAL MIGRATION SCHEME FOR MOBILE AGENTS ROUTING IN A DATA COMMUNICATION NETWORK

B.O. Olofin
Department of Computer Science and Engineering
Obafemi Awolowo Universit, Ile- Ife, Nigeria
bolofin@oauife.edu.ng

E.R. Adagunodo
Department of Computer Science and Engineering
Obafemi Awolowo University, Ile- Ife, Nigeria

G.A. Aderounmu
Department of Computer Science and Engineering
Obafemi Awolowo University, Ile- Ife, Nigeria

ABSTRACT

Traffic analysis of a network is a critical issue in today's fast changing network environment. A network-dependent itinerary is often needed for a mobile agent to travel to multiple hosts and/or destinations efficiently. In this paper, an optimal migration scheme for mobile agent routing in a data communication network was aimed. The routing model was presented as a Chinese Postman Problem (CPP). Combinatorial Optimization was applied to provide all possible itineraries and to compute an optimal path for mobile agents. Look-ahead algorithm was used to determine the link or node availability. The results showed that the proposed model minimizes the network latency and the throughput and thereby improves the mobility properties of mobile agents in a data communication network. It was concluded that the proposed migration scheme for mobile agents routing in a network can be adapted by the mobile agent software developers and network administrators for more effective network management.

Keywords: *Mobile agent, Network routing, CPP, Migration*

1. INTRODUCTION

One of the key challenges faced in a Data Communication Network (DCN) is in managing the network. Network management is a critical issue in today's rapidly changing network environment. DCN consists of heterogeneous network, therefore controlling and managing the traffic in these networks is complex and difficult. Various routing schemes and algorithms to transfer data in a DCN and to manage the traffic in the network had been proposed (Chen and Gerlaet, 1998; Pei et al., 2000). One of the efficient routing schemes is the application of mobile agents in managing and optimizing the network resources (Manvi and Venkataram, 2006).

Deployment of mobile agents in a network decentralizes and distributes the network management functions and proactively carries out administrative tasks thereby improving the reliability and quality of service (Makki and Wunnava, 2006). Mobile agent-based routing approach has been used effectively for network management (Bui et al., 2001). The researchers extensively made use of software agents in finding and maintaining routes.

To increase the effectiveness and efficiency in terms of greater throughput, smaller delay and less packet loss, there is a need for improvement on the migration scheme of the mobile agent routing in a DCN. Hence, the focus of this research is to develop an optimal migration scheme for mobile agents in a DCN using the concept of Arc Routing Problems.

The rest of this paper is arranged as follows: Section 2 discusses the related works while Section 3 presents the proposed framework for Mobile agent routing. Section 4 described the expected results while the conclusion was discussed in Section 5.

2. RELATED WORKS

Deployment of mobile agents in a network had a great impact in controlling congestion in the network. The network traffic generated by mobile agents is very light, since there are very few communications between the agents and the source node during the process of searching. However, as mobile agents move across the network and their number increases, they consume network bandwidth and therefore, they may also cause a traffic deadlock. If there are too many agents in a network, they will introduce too much computational overhead to host or destination machines, which will eventually become very busy and indirectly block the network traffic (Qu and Shen, 2004). Hence, the determination and management of itinerary of the mobile agents is required. Therefore, there is a need for enhancement or improvement on the scheme for mobile agent routing that will choose a route with optimal reliability and reduce the network traffic and eventually improves the overall network performance of mobile agents (Olofin et al., 2009).

There have been tremendous research findings in favour of mobile agents' mobility on a communication network. Qu et al., 2005 developed a mobile agent-based routing algorithm to reduce the network traffic. The scheme of deploying maximum entropy theory in mobile agents' routing process makes the probability distribution to be unbiased. The scheme with load balancing showed significant improvement in the bandwidth utilization of a network therefore it is efficient. But, in reality, assumption that the topology of the network is known is not applicable to dynamic routing, therefore the scheme lacks scalability. Also the mobile agents cannot dynamically adapt to a changing network environment, since the traffic load balancing of the network is determined by the maximum entropy theory based on the known traffic information.

Shivanajay et al., 2002 presented a novel routing scheme for mobile agents in mobile ad hoc networks in order to overcome the shortcomings of on-demand routing protocols in networks. The result shows that the latency and the number of the route discovery of the mobile agents will be reduced by applying the combination of Ant-based and Ad hoc On-demand Distance Vector (AODV) routing protocols. Routing delay is still inherent, because Ant algorithms are used to provide topology information to the nodes. Ants may not perform well when the topology is dynamic and the lifetime of mobile agent is small (Shivanajay et al., 2002).

An itinerary language that models the mobility behaviour of mobile agents was also introduced by Lu and Xu, 2005. The itinerary language called MAIL; a Mobile Agent Itinerary Language allows one to specify the mobile behaviour of agents by defining the syntax and the operational semantics of MAIL. It was proven that MAIL is expressive enough for most migration patterns. One major drawback of MAIL is that it supports static itineraries only.

Also, algebra for programming the agent itineraries was defined by Seng et al., 1999. The iterative behaviour of the agent was modeled by a language of regular itineraries borrowing ideas from regular expression. The weakness of this scheme is that it only presented agent behaviours with respect to their proactive mobility but was limited to a formal specification of itinerary construct.

Also, Ali and Md. Hafiz, 2004 applied a routing algorithm based on Genetic Algorithm to a mobile agent routing. Lightweight agent was presented as an efficient and effective tool for implementing data communication network bandwidth optimization and response time (Olajubu et al., 2008). The work presented routing model for the agents using Travelling Salesman Problem (TSP) concept. The scheme shows that the lightweight agent routing in a network using TSP algorithms is simple, minimal, extensible and flexible

The weakness of this scheme is that TSP, which is a Vertex/ node routing problem is simple to characterize but difficult to solve optimally because the time complexity is exponential. It belongs to the class of NP-hard problems that is unlikely that any efficient algorithm will be developed to solve it i.e. computationally impractical. Researchers normally resort to heuristic procedures to obtain a solution and the result might not be globally optimal. TSP does not allow traversing of nodes more than once. Link and node failure are not taken into consideration in the model i.e. the scheme seems to be static.

A conceptual migration scheme for mobile agent routing in a data communication network was proposed by Olofin et al., 2009. The authors introduced the concept of Chinese Postman Problem (CPP) as the routing model for the Mobile agent. Combinatorial optimization was proposed as a method to provide the best route for the mobile agent and look-ahead algorithm to provide error recovery in the face of link/path failure.

CPP was employed for the mobile agent's migration scheme because of ease of implementation and the feasibility of solution. Also, in real life situation, transportation and traffic congestion occurs mainly on the roads i.e. mostly on the links and little at the vertexes. The model specifically employed the undirected CPP and provides algorithms for both closed and open solutions. CPP does allow traversing of nodes at least once. This will be able to cater for unforeseen link/ node failure during the mobile agent routing process and make provisions for dynamic itineraries. The mobile agent routing will accommodate changes by altering their routing decisions to reflect changes in the network size. That is, the model put into consideration the addition and deletion of nodes and/or links (Olofin et al., 2009).

In this paper, attempt was made to improve the mobility properties of mobile agents in a Data Communication Network by presenting a proper implementation of the proposed model. An optimal migration scheme was proposed to address the problem of traffic congestion and link/ node failure.

3. MOBILE AGENT MIGRATION SCHEME

Mobile agent's migration refers to an agent moving from one execution environment to the other. This usually occurs throughout the agent lifetime. The agent migration process consists of deactivating the agent, capturing its state, transporting the agent to a new location, restoring the agent state, and then resuming the agent execution.

Mobile agents often have a task to collect or deliver data from several predefined sites; migration scheme provides the mobile agents what processes, tasks, actions or procedures it needs to operate to achieve its predefined goal.

3.1 Available Routes Determination

Mobile agents often needs to travel to multiple hosts to perform their tasks, the mobile agent will need to know all the possible itineraries that are available for migration. It is however, important to determine the itinerary at the time the agent is designed or instantiated, because the topology of the network might not be known.

Mobile agent routing is an ordering problem i.e. it must be prescribed in a sequential manner, in which one step has to be completed before the commencement of another. Given the multiplicity of paths in a data communication network, the problem of finding paths is clearly of a combinatorial nature.

Combinatorial optimization technique is used in this paper to provide all the possible itineraries for the mobile agents. The technique employed is the adjacent list representation for the graph data structure as a basis for the traversal algorithm i.e. the modified Depth First Search (DFS) algorithm, to find the edges connected to any particular vertex. The mobile agent will perform a Depth First Search on the adjacent lists provided using the pseudo code in Figure 1.

3.2 Best Path Determination

After knowing all the possible itineraries, mobile agent is faced with the difficulty of knowing which path is optimal in terms of minimal cost, minimal consumption of resources and minimal delay during the routing process.

The best path can be described as a reliable path in which the mobile agent can utilize in a minimum time and at a minimum expense (resources).

In this research, it is noted that the computed shortest path might not be the optimal path. This is based on the fact that distance between two nodes on a network is not the only parameter that determines the traffic between the two nodes. The amount of load a mobile agent carries is also paramount as the agent cannot make use of a link that has a capacity lesser that its size, as shown in Figure 2. Also, the availability of a path has to be considered while computing the best path for mobile agent.

Optimization techniques are also used to determine the implicit route i.e. the optimal itinerary, which returns only a single route for the mobile agent among the available itineraries based on three metrics: the distance, available bandwidth and link availability. This is shown in Figure 3.

Procedure findallpossiblepaths
set Startnode $\leftarrow$ s
set Endnode $\leftarrow$ z
set Stack $\leftarrow$ null
compute A(s)
DFS(s)
End findallpossiblepaths

Procedure DFS(s)
for each v $\in$ A(s) **do**
flag [v] $\leftarrow$ false
SearchDepth(v)
End DFS

Procedure SearchDepth(v);
flag [v] $\leftarrow$ true
Compute A(v)
set stack $\leftarrow$ stack $\cup$ v
for each w $\in$ A(v) **do**
pstack $\leftarrow$ stack $\cup$ w
stack $\leftarrow$ pStack
if flag [w] = false **then**
SearchDepth(w)
else
Computepath(w)
End SearchDepth

Procedure Computepath(x)
Path $\leftarrow$ s $\cup$ z
for each x $\in$ stack **do**
If x $\leq$ z **then**
Path $\leftarrow$ path $\cup$ x
End Computepath

Figure 1: Explicit Route Discovery Specification

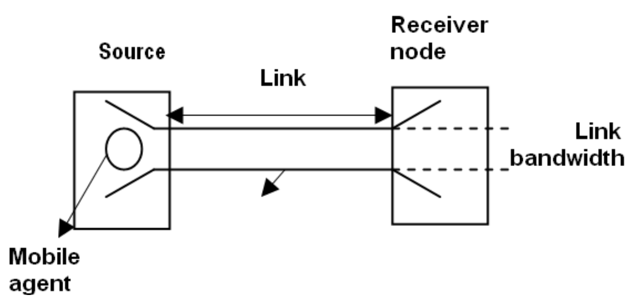

Figure 2: Bandwidth and Latency of a Data Communication Network

Procedure Optimalpath

For Path = 1 to m do
Begin
While ($b < A_p$) AND ($R_p = 1$) do
Compute L_p
end;
For L_p = 1 to n do
Compute S_p
End Optimalpath

Figure 3: Optimal Route Discovery Specification

3.3 Error Detection and Recovery

Error detection and recovery is also a characteristic that a mobile agent must possess. In a dynamic network, where node or links can be added or removed spontaneously, mobile agent must be able to detect the link/ node failure and re-route the network. Any routing algorithm that requires routers to know about every single destination in a network becomes infeasible as the network grows. The storage requirements, communication and update overhead will be costly.

In this research, Look-ahead algorithm was used to determine the link or node availability (Figure 4). The mobile agent will perform a forward checking, to detect a failure, if it exists, the mobile agent will backtrack to the last node it just executed, if not, it launches it operations. It ensures that when the primary (selected) path fails, a new path discovery procedure is initiated, and alternate one will be used to salvage the packet. This feature makes the mobile agent to be fault- tolerant.

Procedure Backtracking (edge)
If edge is connected, **then**
return *True*;
perform *migration*
Else
return *False*
perform **combinatorial analysis**
end Backtracking

Figure 4: Error detection and Recovery Specification

4. Routing Model: CPP

The migration scheme for mobile agent routing in a network is a network optimization problem. In this research, the network optimization technique is required to minimize the consumption of network resources such as bandwidth subject to capacity and demand constraints. Efficient routing of mobile agent in a network is modeled as an Arc routing problem being one of the well known problems in combinatorial optimization. The main objective of an arc routing problem is to minimize the sum of the cost of traversing non-required arcs. Generally speaking, one seeks the cycle that covers all arcs in required arcs R with a minimum associated cost.

To formulate the network optimization problem for mobile agent routing in a data communication network, Chinese Postman Problem (CPP) on an undirected network approach was used. The Chinese Postman model concentrates exclusively on the shortest path. The recurrent theme in routing problems is to minimize the total distance traveled in describing an edge covering tour i.e. in traversing every edge in the network at least once. In this paper, Chinese postman model shifted attention to the amount of bandwidth usage in choosing the best path for the mobile agent.

The migration scheme model can then be formulated as follows:

$$Min \quad \sum_{i=1}^{n}\sum_{j=1}^{n} (W_{ij}X_{ij})A_{ij}R_{ij} \tag{1}$$

Subject to:

$$\sum_{k=1}^{N} X_{ki} - \sum_{k=1}^{N} X_{ki} = 0 \qquad i = 1,\ldots,N \tag{2}$$

$$X_{ij} + X_{ji} \geq 1 \text{ for all arcs } (i,j) \in E \tag{3}$$

$X_{ij} \geq 0$ and is integer (4)

Where

n = the number of nodes in an identified path

X_{ij} = the number of times the arc from node i to node j is traversed

W_{ij} = the distance between node i and node j

A_{ij} = the available bandwidth between node i and node j

R_{ij} , i,j = 1,2,...,n is the zero-one variable that determines whether the connection between node i and node j exists (Value 1) or not (value 2)

Expression (1) is the objective function which is the minimization of the distance required to travel through the network and cover every edge at least once.

Expression (2) expressed the continuity of flow requirement for the network; the number of edges traveled going into any node must equal the number going out.

Expression (3) states that requirement that each edge must be travelled at least once.

Expression (4) is the non-negativity restriction.

5. Model Architecture

Figure 5 shows the framework for the migration scheme for the mobile agent routing. The routing procedure that the mobile agent will utilized is as shown in Figure 6.

6. Simulation Result

Model simulation is carried out for a single mobile agent migration on a data communication network. Network Simulator 3 (NS3) tools were used to simulate the model formulated. The core of NS3 was written in C++ programming language and with Python scripting interface.

Performance comparison of network throughput was performed between the TSP routing algorithm and CPP routing model. The network bandwidth is used as a performance metric for the simulation. The degrees of bandwidth usage between the two schemes were shown in Figure 7. The network bandwidth usage increases as the number of nodes increases on the network, the increase in TSP scheme is significantly higher than the CPP scheme. It is then obvious in this simulation that the CPP scheme has a better performance in optimizing the network bandwidth.

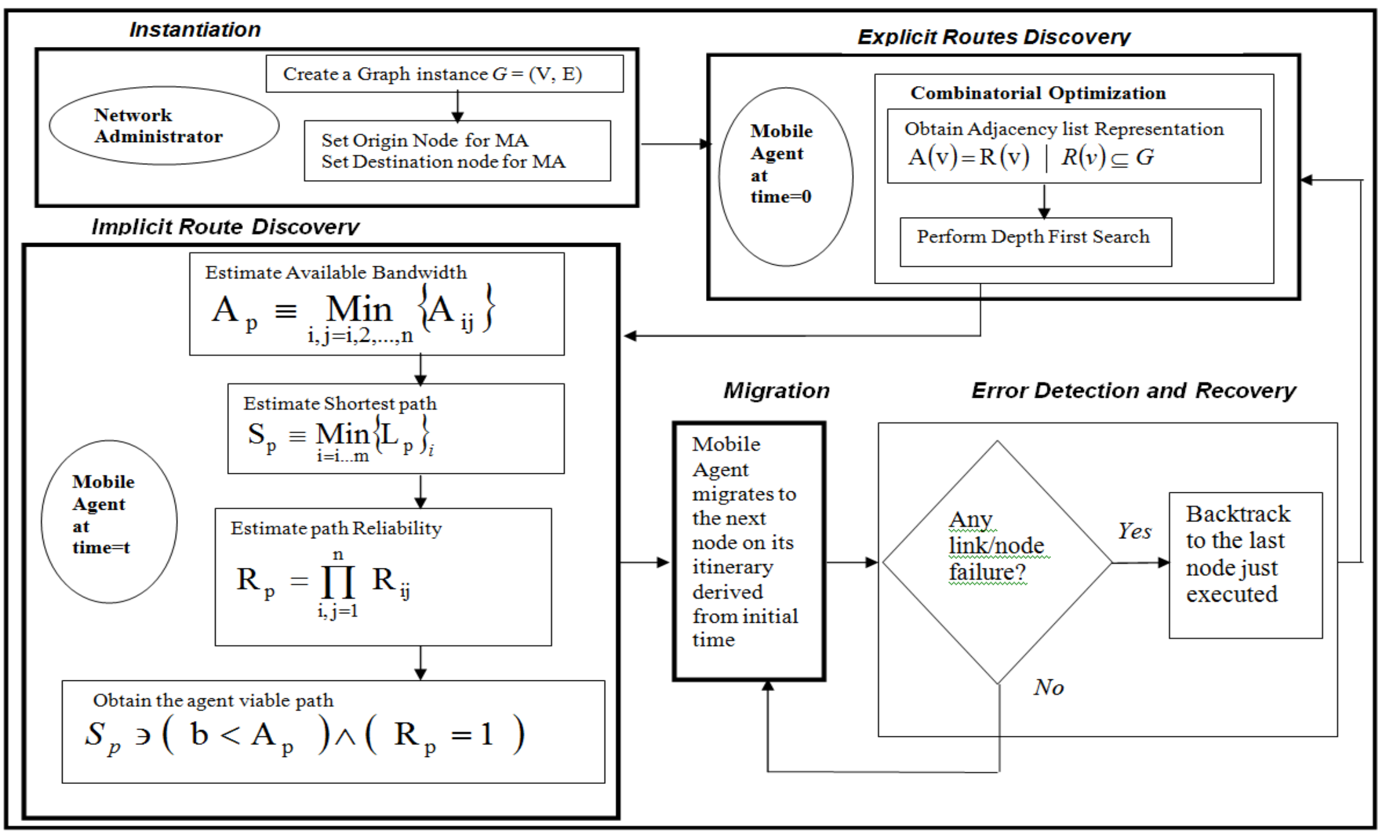

Figure 5: Migration scheme for Mobile Agent Routing in a Network

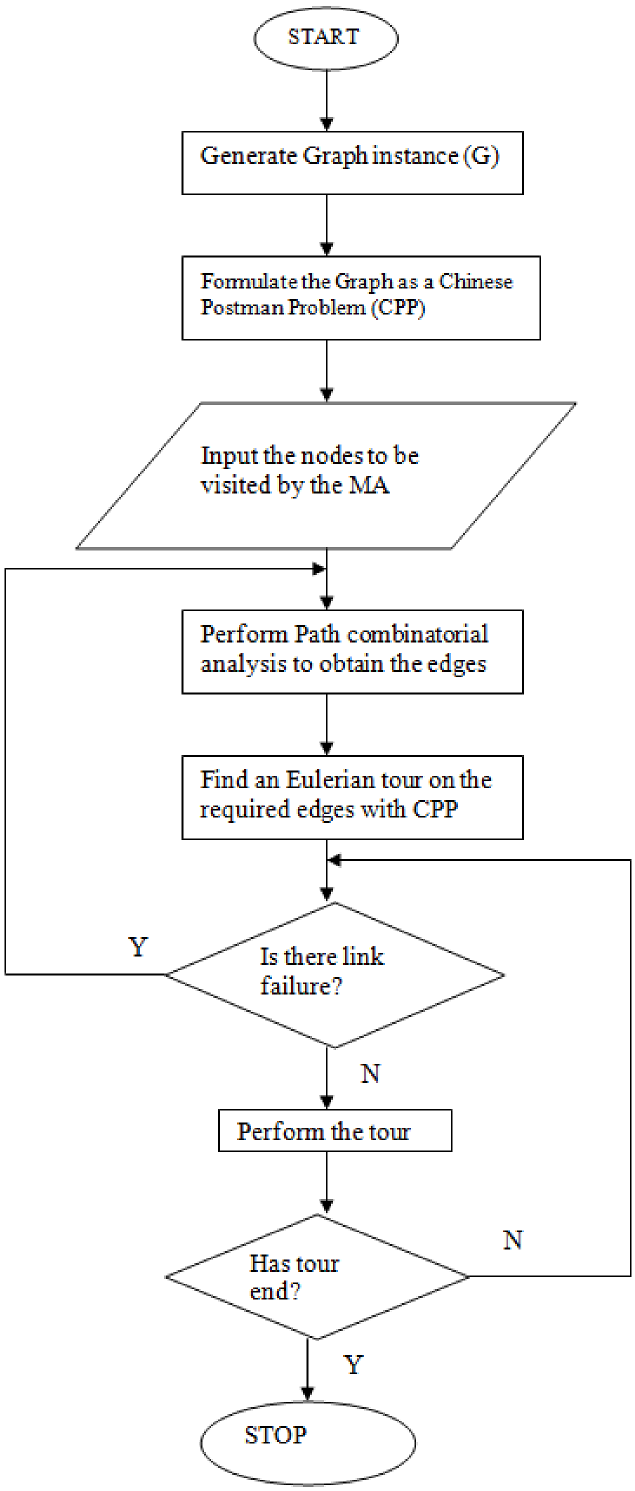

Figure 6: The data flow of the Model

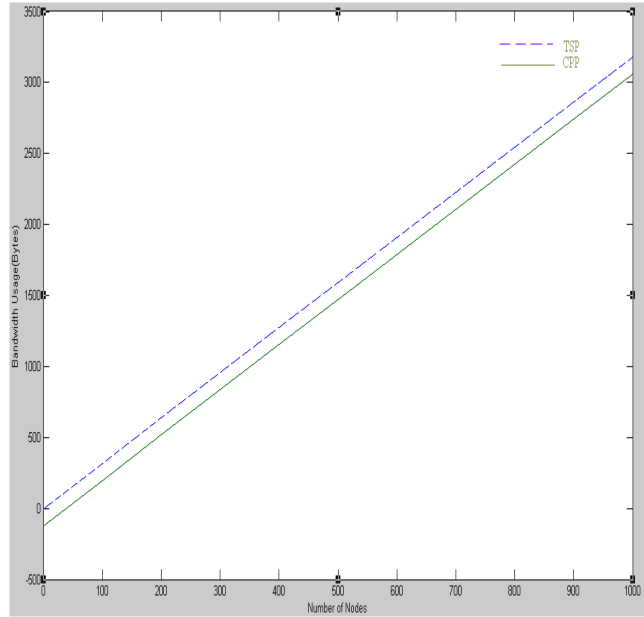

Figure 7: Network Bandwidth

One other performance metric used in this simulation is the response time. The response time of the two schemes were compared. The network response time increases as the number of nodes increases on the network, the increase in TSP scheme is significantly higher than the CPP scheme as shown in Figure 8. It is obvious in this simulation that there is a reduction in the network delay in CPP scheme than TSP scheme, thus CPP scheme have a better performance in increasing the effectiveness of the network in terms of reduced delay.

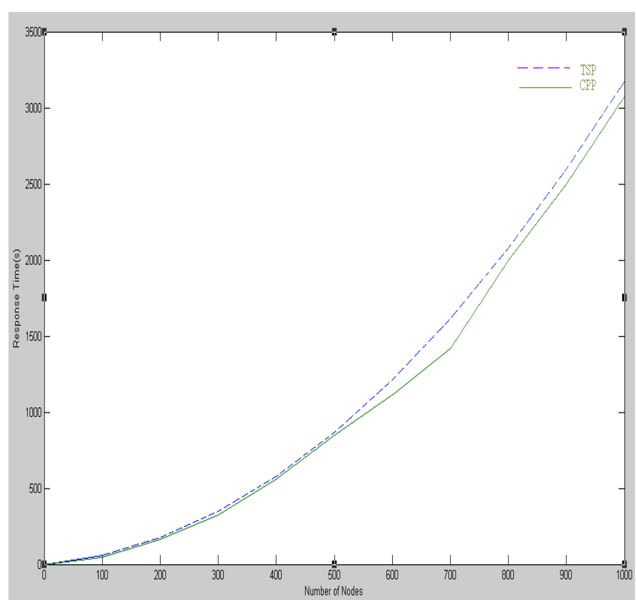

Figure 8 : Response Time

The third performance metric used in this simulation is the Network throughput. The rates of network throughput of the two schemes were compared. The Network throughput rate increases as the number of nodes increases on the network, there is a decrease in CPP scheme than the TSP scheme. This means that the TSP scheme transmits more data than the CPP scheme. It is obvious in this simulation that there is a reduction in the rate of packet loss in TSP scheme than CPP scheme. The TSP scheme does better but with a little significance as shown in Figure 9, thus TSP scheme have a better performance in increasing the effectiveness of the network in terms of reduced packet loss. This is because retransmitting packets by mobile agent due to link/ node failure causes the throughput of the network to decrease.

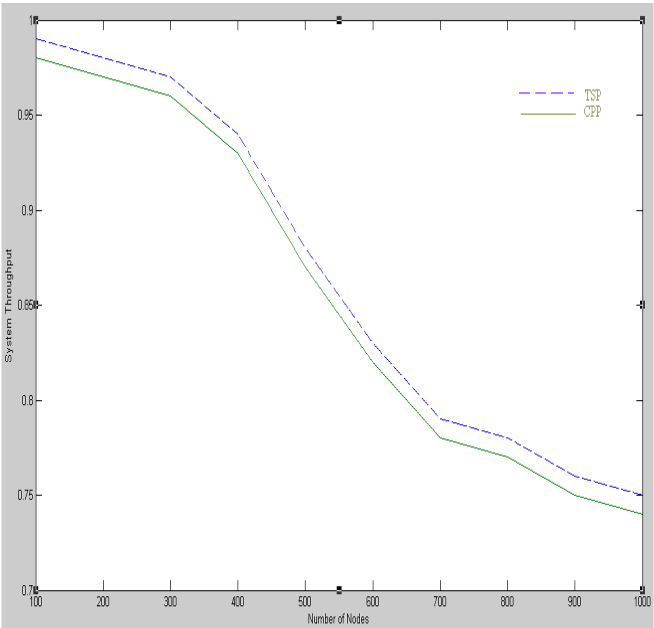

Figure 9: Network throughput

7. Conclusion

In this paper, a migration scheme based on Chinese Postman Problem(CPP) applied to a mobile agent routing in a data communication network was presented. The proposed scheme will choose a route with optimal reliability and reduce the network traffic and eventually improves the overall network performance of mobile agents. a comparative analysis was done using TSP scheme and CPP scheme, the result from the simulation shows that there is improvement in the mobility properties of mobile agent in a network using CPP routing model. The proposed model is able to obtain a better effectiveness in terms of network throughput, reduced delay and packet loss. In conclusion, the scheme optimizes the network function by gathering statistics about the network traffic to deliver the lower latency, highest capacity and maximum reliability despite the limited bandwidth and intermittent failure of the network. The proposed migration scheme for mobile agents routing in a network can be adapted by the mobile agent software developers and network administrators for more effective network management in a minimum time and at a minimum expense (resources).

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