ISSN (Online) : 2278-1021
ISSN (Print) : 2319-5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 3, Issue 6, June 2014

An Optimization Technique For Wireless Mesh Networks

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Abstract: Wireless mesh network is a most popular technology now a days due to its low installation cost, easily deployable, self configurable technology as compared to other competitive technologies**.** Access points/wireless routers and wireless nodes are the important part of this technology. In this paper, we present the optimized routing technique for wireless mesh network based on the Hopfield neural network and mobile agent technology and fuzzy logic system with primary goal to find an optimal route. Mobile agent technique is used to share the information of network conditions. Here, we realized the proposed routing technique through two independent methods. They are both based on the neuro-fuzzy logic. In first method, an optimized route is finding out based on multi criteria optimization in order to provide the best possible usage of resources. In second method, all routing minute to minute information is detected and shared all over the network. In this procedure, mobile agent technology has been proposed here. For optimization of the route, criteria are number of hops, link capacity and link occupancy. These criteria should use network resources as optimally as possible.

Keywords: Mobile agents, Hopfield neural networks, Fuzzy logic, Neuro –fuzzy, optimization,Access points

I. INTRODUCTION

Wireless networking is allowing businesses to develop WANs, MANs, and LANs without a cable plant. The IEEE has developed 802.11 as a standard wireless LANs. The impact of wireless communications has been and will continue to be profound. The standards that define how wireless communication devices interact are quickly converging and soon will allow the creation of a global wireless network that will deliver a wide variety of services. Wireless is convenient and often less expensive to deploy then fixed services but wireless is not perfect. There are limitations, political and technical difficulties that may ultimately prevent wireless technologies from reaching their full potential. Two issues are incompatible standards and device limitations.

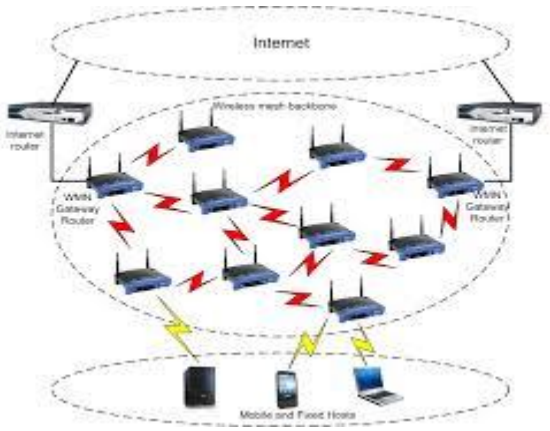

Fig.1 Wireless Mesh Network Architecture

To provide wireless communications within a particular geographical region (a city, for example), an integrated network of base stations must be deployed to provide sufficient radio coverage to all mobile users. The base stations, in turn, must be connected to a central hub called the mobile switching center (MSC). The MSC provides connectivity between the public switched telephone network (PSTN) and the numerous base stations, and ultimately between all of the wireless subscribers in a system. The PSTN forms the global telecommunication grid which connects conventional (land line) telephone switching centers (called central offices) with MSCs throughout the world.

Wireless mesh networks (WMNs) are self-configurable and, self-healing wireless networks. Access point (AP), gateways, mesh clients, mobile nodes, mesh routers are the main components of a wireless mesh networks. In WMNs data is transferred hop by hop. And to forward a packet from source to destination, a number of hops may have to be visited. As the small network is extended to a large network, the chances of degradation of performance and reliability of routing process are more. Mostly several routing protocols used for MANETs are also used for WMNs. But when the size of a WMN is extended to a large, the performance in such a network is going to through poor. In the last few years, a number of routing algorithms for wireless mesh networks has been proposed. But most of the algorithms are designed taking into consideration that all the nodes into network will take full cooperation in routing the packets form source to destination. Also some traditional already existing protocols such as DSR and AODV only takes one parameter ‘minimum hop count’ for routing decisions. Also there are several limitations in the existing protocols. But several other parameters must have to be considered such as signal power, mobility of the node, buffer occupancy, trust level, and maliciously and selfishly of a node on a wireless network. But, the fact that all the nodes in the wireless network will not compulsory full

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cooperates in routing the packets from source to destination. Some nodes may refuse to forward packets as expected and due to this reason the reliability and performance of the network may be degraded. Fluctuations in number of users have influence on a rapidly changing topology. These changes occur randomly and dynamically. Furthermore, ad hoc networks, as opposed to cellular networks, are limited to a higher extent by the battery power of the network nodes. Also, limitations are related to the bandwidth and rate speed. WMN can be a standalone network, but at the same time it can be connected to any other public or private network. Nodes in WMN have to support traffic even in the cases when some of the communicating nodes become out of range. All these reasons, especially frequent network topology changes, make classical routing algorithm inappropriate for these networks.

In this paper we present the routing algorithm for WMNs based on the neuro fuzzy logic, mobile agent technology, and with primary goal to find optimal path through dynamic network topology. This information is used for routing packets into the WMN. For this purpose we used mobile agent technique. Mobile agent logic is realized by the Hopfield neural network, too. In this way updated messages are broadcasted all over the network via optimized flooding technique..

The paper is organized as follows: Section I consist of brief descriptions of a wireless mesh networks. Related work is given in Section II. In Section III basic principles of Hopfield neural network work are given. Mobile technology is explained in section IV. Proposed routing technique is presented in Section V. Some simulation work is given in Section VI. Section VII concludes the paper.

II. RELATED WORK

In [3] S.Kumar et.al proposes a framework for optimal routing in the WMN, an investigation work for the suitability of Big -Bang Crunch (BB-BC), a soft computing based approach to evaluate shortest/ near shortest path. Here, a fuzzy logic based inference mechanism evaluates the cost measure based on throughput, delay, jitter and residual energy at each node. A large number of simulation works has been taken out.
In [4] K.Sasikala proposes a Neuro fuzzy logic routing scheme. The proposed Neuro fuzzy logic approach is characterized by a set of further used for representation of data. In this work, an algorithm NF-AODV is explained. The proposed sheme consists of a well-organized tree construction scheme which manages to decrease data overhead compared to customary ad-hoc routing protocol. To implement the proposed scheme, an auto-configuration scheme is used which provides nodes with topologically correct IP addresses and reduces system overhead. To evaluate the NF-AODV, a number of metrics are used such as average delay, pdf etc.

In [5] Nenad Kajie et.al proposes a hybrid routing protocol for WMNs. In this work Hopfield neural network and mobile agent techniques are used. Here, mobile agent techniques are controlled by the Hopfield neural network. To achieve a better optimization, routing protocol observes real network parameters and real network environment with the help of mobile agent/server technology. The proposed routing protocol is based on link state routing and takes into consideration several parameters such as number of hops, bandwidth, load and delay.

In [6] Nenad Kajic et. al proposes a routing algorithm for MANET. This algorithm is based on neural network. Here mobile agent technology is used to collect the information regarding link status and current updated network conditions. The proposed algorithm is completed in three phases: first, finding the shortest path, second, enabling the physical connection with MANET router, and third, enabling the logical connection with one of the gateways for providing the end MANET router. In case of route recalculation, the proposed algorithm takes into consideration the criteria's such as number of hops, link capacity and link occupancy.

III. HOPFIELD NEURAL NETWORKS

- The Hopfield network consists of a single layer of processing elements where each unit is connected to every other unit in the network other than itself.
- The units in the Hopfield model act as both input and output units.
- Hopfield model is an auto associative memory model, patterns rather than associated patterns pairs, are stored in memory.
- This type of network was described by J.J. Hopfield in 1982. Hopfield network is very simple: it has 'n' neurons which are all networked with each other. A Hopfield network is able to recognize unclear pictures correctly. However, only one picture can be stored at a time. In practical applications one must assume that many pictures will be given, which have to be stored and then classified.
- Training a Hopfield net involves lowering the energy of states that the net should "remember". This allows the net to serve as a context addressable memory system, that is to say, the network will converge to a "remembered" state if it is given only part of the state. The net can be used to recover from a distorted input the trained state that is most similar to that input.
- The two main difference between Hopfield and iterative auto associative net are that, in the Hopfield net,
  - Only one unit updates its activation at a time, and
  - Each unit continues to receive an external signal in addition to the signal from the other units in the net.
- This is called associative memory because it recovers memories on the basis of similarity. For e.g., if we train a Hopfield a net with five units so that the state (1,0,1,0, 1) is an energy minimum, and we give the network the state (1,0,0,0,1) it will converge to (1,0,1,0,1). Thus, the network is properly trained when the energy of states which the network should remember are local minima.

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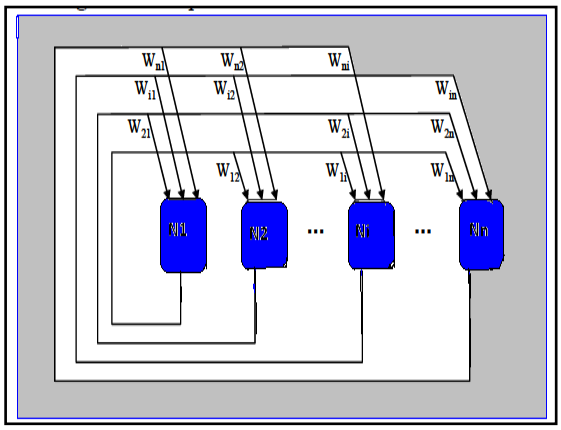

Fig.2: Hopfield Neural Network

IV. MOBILE AGENT TECHNOLOGY

Mobile agent technology has been promoted as an emerging technology that makes it much easier to design, implement, and maintain distributed systems.

Mobile agents:

- Performs some processing at each host.
- Are small software entities.
- Are active objects.
- Are autonomous programs.
- Contains code, state and attributes.
- Decide when and where to move next.
- Having two types of mobility i.e. strong mobility and weak mobility.
- Encapsulate protocols.
- Execute asynchronously.
- Are robust and fast tolerant.
- Have several advantages such as reduced communication costs, asynchronous execution, direct manipulation, dynamic deployment of software, easy developments of distributed applications; reduce bandwidth consumption and network loads.

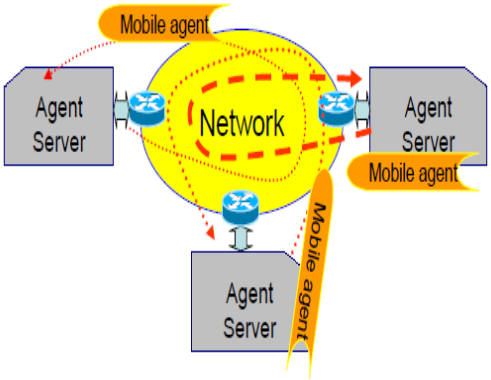

Fig.3 : Mobile Agent Technique

Java is one of the supporting languages for mobile agent technology. Mobile agent technology have several applications i.e. remote information retrieval, network management, cloud computing, mobile computing , software testing, active networking, and active documents.

- In mobile agent system, the agent visits the each node one by one and collects the necessary information from each node. Each node having a agent server. Mobile agent can easily communicate with agent server for sharing the information on the network.
- Mobile agents cooperate and communicate each other on the network.
- Mobile agents leave and collect information with each node with the help of agent server integrated with each node on the network.
- Mobile agent updates the routing table with the help of information collected by it and after this work; it also collects local information at this stage and then visit the next node.
- To minimize the overhead on the network the size of mobile agent must be small as well as possible.
- The events in the life cycle of the mobile agents are: (i) retraction (ii)disposal (iii)communication (iv) creation (v) dispatch (vi) cloning (vii) deactivation (viii) activation.
- Every mobile agent can access any node at an arbitrary time and share network information with its routing table.
- Every agent server can generate any number of mobile agents on the network. Every mobile agent has some path and needs to go through all known routers in network and come back to all its agents' server.
- Role of a mobile agent is to travel through a network and to discover every kind of changes, producing the information on it.
- Any change in the network can change all previously found "best" routes, and this procedure has to be repeated.
- Besides that link status changes have to be detected and observed by neural network. After recalculation, traffic can be rerouted if there is a better solution.

V. PROPOSED ROUTING TECHNIQUE

In the proposed algorithm, the procedure starts with the connection of a new user to a network. The WMN router detects the new device. We organize routing process into several phases. To accomplish the proposed routing algorithm, the following parts have to be followed:

Part 1: Finding the shortest WMN routes (should be realized by software in mobile device),

Part 2: Enabling the physical connection with WMN router (which requires changing of the routing table data in the WMN router),

Part 3: Enabling the logical connection with one of the gateways for providing the connectivity to the distribution system over the end WMN router.

After routers initialization, based on information in routing tables, neural network finds the route to the first (nearest) gateway in the observed network topology.

The proposed algorithm completes its process within following steps:

Step 1. Software initialization.
Step 2. Reading network configuration from connected node.
Step 3. Finding route to first gateway node.
Step 4. Establish route connection.
Step 5. If there are no more gateway nodes then go to step 8.

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Step 6. Otherwise Calculate route cost.
Step 7. Calculate minimal route cost.
Step 8. Establish route connection.

Mobile device is going to be connected to this gateway. If there is more than one gateway, proposed algorithm will start the process of routing recalculations in order to find more suitable gateway and appropriate route to it. In this case, the criteria are number of hops, link capacity and link occupancy. These criteria should use network resources as optimally as possible. If such gateway and route is found, algorithm should perform the rerouting.

Here the rerouting process works basis on the fuzzy logic system to analysis the best optimized route on the wireless network. The Fuzzy Logic is an innovative approach to help control non-repeating or unpredictable systems control accuracy. It uses a list of rules rather than complicated mathematical expression. Fuzzy Logic was introduced by L.A. Zadeh in 1965. Fuzzy Logic is also known as fuzzy rule based system and this is a non linear mapping technique of input data into output. The system is based on the fuzzy inference system. The major components of the system consist of the knowledge base, decision making, fuzzification and defuzzification.

The fuzzy logic system works on the inputs: number of hops, link capacity, and link occupancy. Here "Mamdani fuzzy system" has been used. The output variable is used as route. Our problem is to find the optimal and suitable route from source to the destination based on hop count, link capacity and link occupancy.

Fuzzy sets: A fuzzy set can be defined mathematically by assigning to each possible individual in the universe of discourse a value representing its grade of membership in the fuzzy set. This grade corresponds to the degree to which that individual is similar or compatible with the concept represented by the fuzzy set. Thus individual may belong in the fuzzy set to a greater or lesser degree as indicated by a larger or smaller membership grade. These membership grades are very often represented by real-number values ranging in the closed interval between 0 and 1.

The fuzzy sets for input variables and output variable are explained here:

The sets, Low (from 0 to 0.4), Medium (from 0.2 to 0.8) and High (from 0.6 to 1.0) have been used for the input parameter Hop Count.

The sets, Low (from 0 to 0.4), Medium (from 0.2 to 0.8) and High (from 0.6 to 1.0) have been used for the input parameter Link Capacity.

The sets, Low (from 0 to 0.4), Medium (from 0.2 to 0.8) and High (from 0.6 to 1.0) have been used for the input parameter Link Occupancy.

The sets, Low (from 0 to 0.4), Medium (from 0.2 to 0.8) and High (from 0.6 to 1.0) have been used for the output parameter 'Route'.

To implement this fuzzy based scheme twenty seven fuzzy rules have been derived. One of them is explained as under:

"If (Hop_Count is low) and (Link_Capacity is medium) and (Link_Occupancy is medium) then (Route is high)"

- Link status changes have to be detected and observed by neural network. After recalculation with the help of fuzzy logic system , traffic can be rerouted if there is a better solution. This sub procedure starts every time when these changes are detected.

VI. SIMULATION RESULTS

The Proposed routing algorithm in wireless mesh network is realized in Matlab 7.0. We used dynamically created network topology based on arbitrary number nodes. All links are bi-directional with different parameters (explaining the links status and network topology) for different directions. Network topology, connectivity and number of nodes are changeable and user can define them through appropriate Graphic User Interface. Each link is described with three parameters: distance, capacity and traffic density. All values for all parameters are randomly generated and scaled to the interval [0-1].

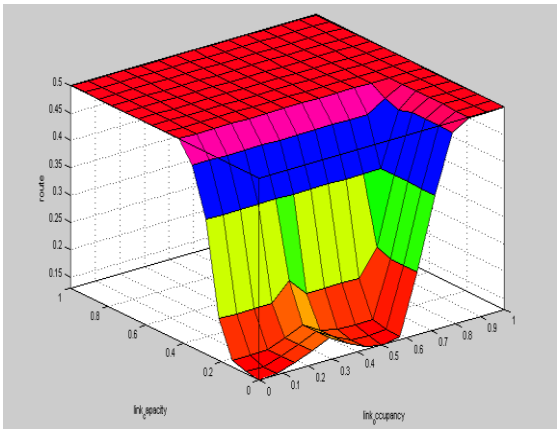

Fig.4 : 'Route' O/P w.r.t. 'Link Capacity' and 'Link Occupancy'

In **figure 4**the inputs of the protocol (link capacity and link occupancy) are on the horizontal axes and the output (route) is on the vertical axis.

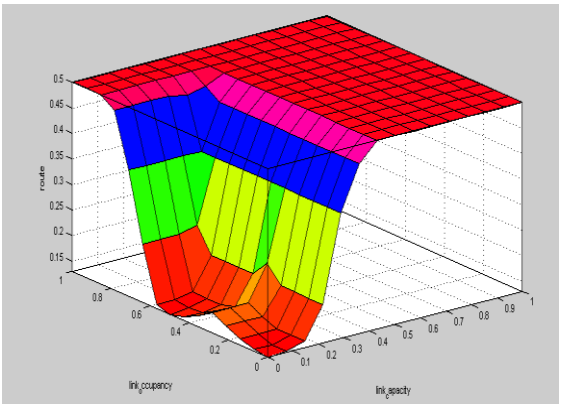

Fig.5 : 'Route' O/P w.r.t. 'Link Occuancy' and 'Link Capacity'

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In **figure 5** the inputs of the protocol (link occupancy and link capacity) are on the horizontal axes and the output (route) is on the vertical axis.

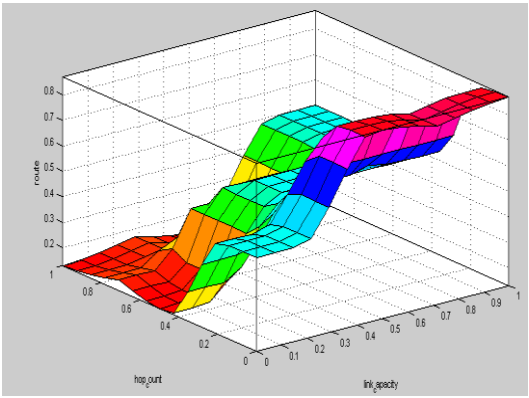

Fig.6 : 'Route' O/P w.r.t. 'Hop Count' and 'Link Capacity'

In **figure6 the** inputs of the protocol (hop count and link capacity) are on the horizontal axes and the output (route) is on the vertical axis.

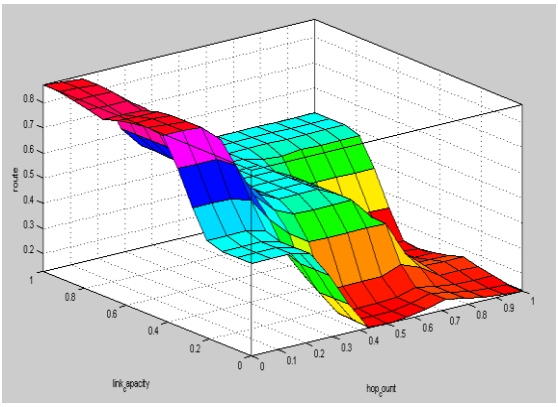

Fig.7: 'Route' O/P w.r.t. 'Link Capacity' and 'Hop Count'

In **figure 7** the inputs of the protocol (link capacity and hop count) are on the horizontal axes and the output (route) is on the vertical axis.

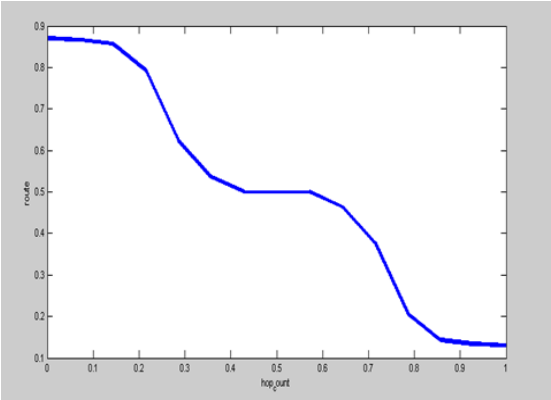

Fig.8: 'Route' O/P w.r.t. 'Hop Count' at constant 'link occupancy' and at constant 'link capacity'.

The figure 8 represents the value of the route with respect the number of hop count when the link capacity value and link occupancy are remains constant.

A number of test cases have been conducted. Some of them are described as below:

Test case number	Hop Count	Link Capacity	Link Occupancy	Route
Test case no.1	0.978(high)	0.0873(low)	0.968(high)	0.131(low)
Test case no. 2	0.968(high)	0.0970(low)	0.077(low)	0.138(low)
Test case no.3	0.978(high)	0.998(high)	0.147(low)	0.144(low)
Test case no.4	0.139(low)	0.5(medium)	0.464(medium)	0.857(high)
Test case no.5	0.346(low)	0.48(medium)	0.389(low)	0.798(high)

- The simulation results presents that when hop count is high, link capacity is also high, and link occupancy is any type of value the route is not optimize at this stage. But at low hop count value, medium link capacity, and medium occupancy, the value of route optimize got its high stage. But along this if the values of link capacity and link occupancy go to low stage then as a result the route optimizes value comes to its decreasing stage. These experimental results indicate that hop count and link capacity factors are also main factors in terms of cost of the route. The proposed scheme works well at the medium link capacity also.

VII. CONCLUSION

Wireless networks and the usage of mobile devices are becoming popular in recent days, especially in creating ad-hoc networks. There is thus scope for developing mobile systems, where devices take an active part of creating a network infrastructure, and can actually be used to route data between networks. This research proposes to assess different models of the usage of static and mobile agents to determine the best route through ad-hoc networks. The determination of this route is a complex one, and requires research into the best metrics to identify the best path, such as memory capacity, network performance, processing capabilities, cost, and so on. Optimization refers to the art and science of allocating scarce resources to the best possible effect. Here, an effective and efficient optimized route selection technique for wireless mesh network has been proposed. This technique converges to a highly optimized path set very fast, and no message exchange overhead. The proposed routing technique can find the most optimized path set between any two nodes and there will be no need to discover new paths in the on demand routing algorithm. Here, new multi criteria optimized route selection technique using neuro fuzzy logic for WMN is presented. We have created new technique based on multi criteria optimization. We have analyzed a number of parameters to provide optimized usage of network resources. For this purposes, two techniques are used here, one is neuro-fuzzy logic and second is mobile agent technology. Our proposed routing technique is scalable and it is adapted for dynamic network topology and real network environments.

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