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Geographic location based STR protocol in Wireless Zigbee Networks

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Abstract—Zigbee is the emerging industrial standard for ad hoc networks. Zigbee is expected to be used in wireless sensor networks for remote monitoring, home control, and industrial automation, due to its characteristics such as low data rate, low price, and low power consumption. Since tree routing does not require any routing tables to send the packet to the destination, it can be used in zigbee that have limited resources. Even though the destination is located nearby, tree routing has a major problem that it follows the tree topology to the destination. We propose the shortcut tree routing(STR) protocol to reduce the routing cost of zigbee tree routing(ZTR) by using the neighbor table and also the overhead is further reduced by introducing a concept called geographic location based STR routing. In zigbee tree routing algorithm, it suggest forwarding the packet to the neighbor node if it can reduce the routing cost to the destination. Simulation results show that the shortcut tree routing algorithm with geographic location reduces overhead, route cost and hop count to a large extend than ZTR and as well as STR.

Keywords —STR(Shortcut tree routing), ZTR(Zigbee tree routing),WSN,MANET

INTRODUCTION

Wireless networks are always preferred since the beginning of invention due to their natural mobility and scalability. Due to reduced cost and enhanced technology wireless networks have much more preferences than wired networks. Zigbee is a worldwide standard of wireless networks. The main goal is to provide low-power, low-cost, flexible, reliable, and scalable wireless products. Apart from other personal area standards such as USB,UWB and bluetooth, zigbee networks supports upto thousands of devices in a network.The zigbee networks can be easily extended on the basis of size and coverage area due to its self-forming and self-healing capability,zigbee provides mesh and star topology. Apart from many other useful functions from the zigbee network layer,tree routing algorithm provides much more simple and reliable routing[2]. The network addresses in zigbee are assigned using a distributed addressing scheme that is designed to provide every potential parent with a finite sub block of network addresses. Every node in zigbee is assigned with a 16 bit unique address dynamically either using a distributed or stochastic addressing scheme. Due to distributed addressing scheme, the network builds up a tree topology, each device in the network can provide the address space of its descendant. If the destination address is placed in the address space of a particular node, the node forwards the packet to one of its child nodes. Else, it forwards the packet to its parent node. The parent or child node which receives the packet selects the next hop node according to the destination address in the same manner. Tree routing algorithm can find the next hop node for a given destination address without making use of routing tables. However, [4] a sender may not know the destination, whether it is located nearby or if it's not in the sub-tree which the sender is contained in, because tree routing concerns only about the parent and descendants of the sender node. Although the tree routing is efficient in the view point of memory usage, the routing cost is sometimes not efficient. This paper proposes the shortcut tree routing with geographic location algorithm to archive both memory efficiency and routing efficiency.[13]Simulation and emulation are valuable techniques for the evaluation of algorithms and protocols used in mobile ad-hoc networks. However, these techniques always require the simplification of real-world properties such as radio characteristics or node mobility. It has been shown that this may lead to results and conclusions which do not reflect the behavior of ad-hoc networks in the real world. Various prototype implementations demonstrate that even simple protocols such as flooding do not behave as it was predicted by earlier simulation. To overcome this problem, real-world experiments are required. Adaptive Demand-Driven Multicast Routing (ADMR) is a multicast routing protocol designed for ad hoc networks in which nodes collaborate with each other to deliver packets. Data is multicast by sending packets to group addresses rather than individual node addresses. These packets will then be forwarded towards all the receivers belonging to a particular group along a forwarding tree established by the protocol. ADMR is fairly sophisticated[14].

The scheme proposed in this paper improves the zigbee routing algorithm by employing neighbor tables, which are part of the existing zigbee network specification. To overcome the overhead of routing along the tree, we suggest nodes to check their neighbor tables before sending the data to its parent or children. If the table contains a neighbor node that enables reducing the routing cost to the destination, it can be the next hop node for the given destination, instead of the parent or a child node. Further the routing overhead is reduced

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by introducing a concept of geographic location based routing If more than one neighbour node has information of the destination node, geographical information will be used to select the next node. Overhead will be reduced further by using geographical information.

This paper is mainly a comparison between ZTR and STR and STR with geographic location. First of all we propose an STR routing protocol by making use of geographic locations, it resolves the main reasons of overall network degradation of ZTR which are detour path problem and traffic concentration problem. Further evaluations are done to reduce the network overhead. In zigbee network,[3] the routing protocols are diverse hence the users can adopt an optimal routing strategy according to their needs. The reactive routing protocol in zigbee, that is AODVjr is a routing protocol in MANET. There are a number of other routing protocols in MANET similar to zigbee in which optimal routing path for arbitrary source and destination pair through on-demand route discovery pattern. In such cases it requires route discovery process on each communication thereby increasing route discovery overhead and memory consumption. And also another concern is the flooding of route discovery packets can further degrade the environment.

Wireless network is a collection of nodes, each node is equipped with a wireless transmitter and receiver they communicate with each other via bidirectional wireless links either directly or indirectly. The major advantage of wireless networks is the data communication between two nodes by maintaining their mobility[18]. However wireless communication is limited to the rang of transmitters .That means two nodes cannot communicate with each other when the distance between the nodes is beyond the communication range. This problem can be avoided by indulging intermediate nodes to relay data transmission. This can be done by dividing into two types of networks mainly single-hop and multi-hop. In a single-hop network, all the nodes within the same communication range can communicate directly with each other, whereas in a multi-hop network, they rely on their intermediate nodes to transmit if the destination node is beyond their transmission range.

MOTIVATION

In MANET [13] the routing protocols can be divided into two types: reactive routing protocols and pro-active routing protocols. In reactive routing protocol, it requires a route discovery procedure for the transmission. The two major dis-advantages of this type of protocols is that it may cause flooding of route discovery packets and may also cause long delay if there is no data packet to transmit in order to find the routing path. AODV[10],TORA[12],DSR[11]are the examples of reactive routing protocols. On the other hand in pro-active routing protocols, periodically updates the topology information, hence it always has an optimal routing path. The examples are OLSR[8], DSDV[9].Whether proactive or reactive, it provides optimal routing path but the routing table size is too big to store all the routing paths.

The traffic patterns are any-to-any, many-to-one and one-to-many[15].In any-to-any pattern, all nodes can be a source or a destination packet. In many-to-one there will be one destination and this destination collects information from all other network devices. On the other hand one-to-many can have one source and that particular source is required to transmit packets to all other devices. An example of many-to-one is CTP[16]. In the proposed system, two principles for wireless routing protocol design: data path validation and adaptive beaconing. It evaluates these principles in the context of CTP Noe, an implementation of the Collection Tree Protocol (CTP). CTP is a routing protocol that computes any cast routes to a single or a small number of designated sinks in a wireless sensor network. Four goals motivate the need for data path validation and adaptive beaconing:

Reliability: a protocol should deliver at least 90% of end-to-end packets when a route exists, even under challenging network conditions. 99.9% delivery should be achievable without end-to-end mechanisms.

Robustness: it should be able to operate without tuning or configuration in a wide range of network conditions, topologies, workloads, and environments.

Efficiency: it should deliver packets with the minimum amount of transmissions across the network and requiring little state.

Hardware Independence: it should achieve the three above goals without assuming specific radio chip features, as sensor networks use a wide range of platforms.

RPL[18] is an example of one-to-many traffic pattern, RPL (IPv6 Routing Protocol for Low Power and Lossy Networks) is the IETF standard protocol based on CTP. RPL constructs a destination oriented directed acyclic graph (DODAG) to optimize the many-to-one traffic pattern. Every device in the DODAG [5] establishes the optimal routing path to the destination using a single route request from the destination, which may be the gateway of a network. The DODAG significantly reduces the route discovery overhead and routing table size, because it requires only one time of route discovery from the destination comparing with MANET routing protocols requiring all the individual sources to invoke route discovery to the same destination.[7] The main advantage of these protocols is that they significantly reduce the route discovery overhead by concentrating on the many-to-one and one-to-many traffic. Even though they can support the any-to-any traffic pattern, a routing path is inefficient by traversing along the tree topology and they also suffer from detour path and traffic concentration problems like zigbee tree routing.

On the other hand, zigbee tree routing (ZTR) [6] prevents the route discovery overhead in both memory and bandwidth using the distributed block addressing scheme. In ZTR, since each node is assigned a hierarchical address, a source or an intermediate node only decides whether to forward a packet to the parent or one of the children by comparing its address with the destination address. The most benefit of ZTR is that any source node can transmit a packet to an arbitrary destination in a network without any route discovery overheads. Due to this efficiency, ZTR is considered as a promising protocol for

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resource constrained devices in diverse applications such as smart grid project and Internet of Things. However, in ZTR, packets are forwarded along the tree topology to the destination even if the destination is located nearby. Thus, ZTR cannot provide the optimal routing path, while it does not require any route discovery overhead.

In this paper, in additional to the inefficient routing path of ZTR [17], we have identified that ZTR suffers from performance degradation when all the packets are concentrated on the tree links. We demonstrate these problems of the ZTR by the network simulation, and prove that STR significantly enhances overall network performances such as packet delivery ratio, end-to-end latency, path stretch and so on.The mathematical analyses are also provided in this paper to prove that STR alleviates the traffic load concentrated on the tree links as well as provides an efficient routing path without loop.

SHORTCUT TREE ROUTING ALGORITHM

Here proposed the shortcut tree routing algorithm that improves existing zigbee tree routing by using the neighbor table[1]. In other words, the proposed algorithm basically follows zigbee tree routing algorithm, but chooses neighbor nodes as next hop nodes if the routing cost to the destination can be reduced. The neighbor table that we use in the proposed algorithm is defined in the zigbee specification, so we don't need to make an effort to search neighbor list. In order to choose the next hop node that can reduce the routing cost, the remaining hop count from the next hop node to the destination is computed for all the neighbor nodes including parent and children nodes.

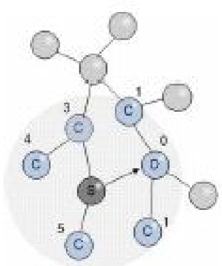

Fig.1.Candidates for nexthop

Fig.1 shows, the remaining hops to the destination for each neighbor can be computed assuming that the route from the neighbor to the destination goes along the tree. In the above In Figure.1, the route cost can be minimized if the sender transmits the data directly to the destination. Find_NextHopAddr() is the algorithm for an intermediate or source node to select the next hop node which has the minimum remaining hop count for the given destination. Because the proposed algorithm follows fundamentally the zigbee tree routing, the parent or child node is selected as the next hop node in lines 2-3. In addition, the remaining routing cost when we follow zigbee tree routing is stored into minNHRouteCost.

In line 4-13, intermediate or source nodes check the remaining routing cost myRouteCost when selecting a neighbor node as the next hop node. The remaining routing cost is calculated based on the remaining hop count to the destination assuming that the packet goes along the zigbee tree routing. In order to calculate the remaining hop count, the hierarchical address structure is used.

By comparing whether the address of a neighbor node is contained in the address space that contains the destination address in each level (AddrRange[]), we can find the root of the common sub-tree that contains both the neighbor node and the destination in line 5-7. Among several common sub-trees, the root of the highest level common sub-tree can be the reference point for the calculations as in Fig. 2. The dotted node is the root of the highest level common sub-tree, and the number besides it indicates its tree level. Based on this reference level, we can calculate the remaining hop count using the equation (level of source node – highest level of on sub-tree) + (level of destination node – highest level of on sub-tree). Since the route path goes up to the parent which contains the destination and goes down to the destination in the tree routing, the proposed algorithm computes the route cost in the same way the tree routing does. If myRouteCost is less than the existing minNHRouteCost, the next hop node NHDstAddr is replaced with that neighbor node and minNHRouteCost is also changed to myRouteCost. Therefore, we can find the next hop node that has the minimum remaining routing cost among all the neighbors, including parent and children nodes. If there is no neighbor node that has smaller remaining hop count than the parent or some child node, the next hop node is determined by the regular zigbee tree routing.

TABLE.1 ALGORITHM TO CHOOSE NEXT HOP NODE FOR THE GIVEN DST ADDR

Input: dstAddr
Output: NHDstAddr
begin
1.depth_dstAddr=Find_AddrRange(dstAddr,0,0)
2.Assign the next hop of tree routing to NHDstAddr
3.Assign the remaining hop count when selecting NHDstAddr to minNHR outocost
4.for each(neighbor n in neighbor table)
5. i=0
6. While (n is in AddrRange[i+1]&&i<depth_dstAddr)
7. ++i
8. myRouteCost=(depth_dstAddr-i)+(depth(n2)-i)
9. if(minNHRouteCost>myRouteCost)
10. NHDstAddr=n
11. minNHRouteCost = myRouteCost
12. end if
13. end for each
End

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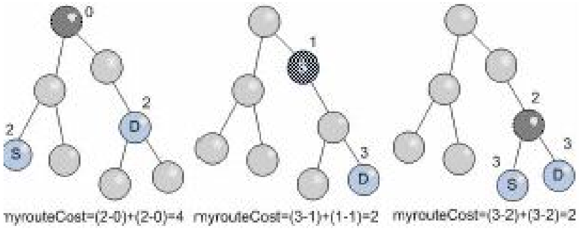

Fig.2. Calculation of Route Cost when following zigbee tree routing

In order to calculate the remaining hops in table 1, we need to compute the address space in which the destination address is contained at each level of the tree together with the depth of the destination. The Find_AddrRange (dstAddr, startAddr, curDepth) function in the algorithm to get AddrRange[] and depth_dstAddr. The address space of destination AddrRange[] can be obtained by finding its ancestor nodes in each level and calculating the address space according to the zigbee's address assignment scheme. The Find_AddrRange() is a recursive function that has the arguments startAddr, curDepth, and dstAddr. A startAddr is the address of the ancestor node at curDepth for the given destination dstAddr. This function is started with startAddr 0 and curDepth 0 by calling from the Find_NextHopAddr() function, and returns the address space in which the destination address is contained at each depth, AddrRange[],and the depth of the destination, depth_dstAddr.
Although the next hop is selected based on the local minimum in the shortcut tree routing algorithm, loops never occur because the remaining hops are computed based on the tree routing. For instance, the route to the destination from the parent or child of a node that received a packet from a certain node v has always smaller remaining hops than from the node v.

TABLE.2.ALGORITHM TO FIND ADDRESS RANGE OF DESTINATION

Input: dstAddr,startAddr,curDepth
Output: depth_dstAddr,AddrRange[depth_dstAddr]
begin
1.if(dstAddr=startAddr
2.return curDepth
3.else
4.for i=1 to Rm
5.is(dstAddr is in the address space of i^{th} router)
6. store address space of i^{th} router to AddrRange[curDepth+1]
7.return Find_AddrRange(dstAddr,i^{th} router,curDepth+1)
8.end if
9.end for
10.if Cm-Rm>0)
11.if (dstAddr is the end device of startAddr)
12.store dstAddr to AddrRange[curDepth+1]
13.return curDepth+1
14.end if
15.end if
16.end if
end

STR is not always optimal in aspect of end-to-end hop distance. It is because, next hop node is selected based on local information like 1-hop neighbour table. In some cases, there may be more than one neighbour nodes with one hop distance. Sending node will be confused to which neighbour it should forward the data, hence we introduce a scheme based on geographic routing. In this scheme each node will keep geographic location of the destination .For ex, if the destination is located at the North side of the network, sending node will send data to the neighbour node in North side

SYSTEM ENVIRONMENT

The particular system is designed using four phases. They are Environmental Setup, Zigbee tree routing, Shortcut tree routing and STR protocol with geographic location.

Environmental Setup

In this module the simulation environment is created using java. The environment consist of nodes that are added on demand, each node is assigned with name, IP address, x and y axis. The speed of the nodes can be adjusted. If we click on a particular node its corresponding details will be displayed. Each node in the network can act as both sender and receiver.

Zigbee Tree Routing

The zigbee network provides functionality such as dynamic network formation, addressing, routing, and discovering 1 hop neighbors. The size of the network address is 16 bits, so zigbee is capable to accept about 65535 devices in a network, and the network address is assigned in a hierarchical tree structure. zigbee provides not only star topology, but also mesh topology. After around a decade of active on wireless sensor networks, recent standards released are stimulating the development of commercial products. One of these standards is ZigBee. [15]This article highlights some of the lessons from the field that went into the standard. It also describes the ecosystem emerging around Zigbee, and the enabling trends in that ecosystem. Besides, the self-formation and self-healing features makes zigbee more attractive. The deployed Zigbee devices automatically construct the network, and then changes such as joining/leaving of devices are automatically reflected in the network configuration. ZTR is deigned for resourse constrained zigbee devices to choose multihop routing path without any route discovery procedure.It works based on hierarchical addressing scheme.
The addressing scheme is described as follows:
Cm(MaxChildren),Rm(MaxRouters),andLm(MaxDepth)respectively. Cm, Rm, and Lm are defined as the maximum number of children a parent may have, the maximum number of routers a parent may have as children, and the maximum tree level of a network in zigbee standard, respectively,

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$$Cskip(d) = \begin{cases} 1 + Cm \cdot (Lm - d - 1), & \text{if } Rm = 1, \\ \dfrac{1 + Cm - Rm - Cm \cdot Rm^{Lm-d-1}}{1 - Rm}, & \text{otherwise,} \end{cases}$$

when a packet is routed through several hops towards the destination even though it is within the range of sender's 2-hop transmission range. To solve this detour path problem of ZTR, zigbee specification has defined the direct transmission rule that allows a coordinator or a router to transmit a packet directly to the destination without decision of the routing protocol, if the corresponding destination is in the neighbor table. However, this method cannot fundamentally solve the detour path problem of tree routing. In case that the destination is located more than 2-hop distance away from a source node, we cannot apply the direct transmission rule. In addition to the detour path problem, ZTR has the traffic concentration problem due to limited tree links. Since all the packets pass through only tree links, especially around the root node, severe congestion and collision of packets are concentrated on the limited tree links. This symptom becomes worse and worse as the number of packets increases, and it finally causes the degradation of the packet delivery ratio, end-to-end latency, and other network performances. Thus we propose STR protocol in order to reduce the network overhead produced by ZTR.

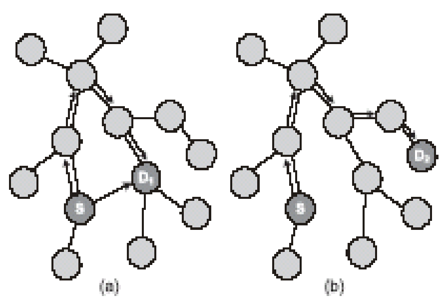

Fig.3. Zigbee tree routing

Shortcut Tree Routing

We propose the shortcut tree routing algorithm that improves existing zigbee tree routing by using the neighbor table. In other words, the proposed algorithm basically follows zigbee tree routing algorithm, but chooses neighbor nodes as next hop nodes if the routing cost to the destination can be reduced. The neighbor table that we use in the proposed algorithm is defined in the zigbee specification, so we don't need to make an effort to search neighbor list. In order to choose the next hop node that can reduce the routing cost, the remaining hop count from the next hop node to the destination is computed for all the neighbor nodes including parent and children nodes. As Fig.4 shows, the remaining hops to the destination for each neighbor can be computed assuming that the route from the neighbor to the destination goes along the tree. In the above Fig. 4, the route cost can be minimized if the sender transmits the data directly to the destination.

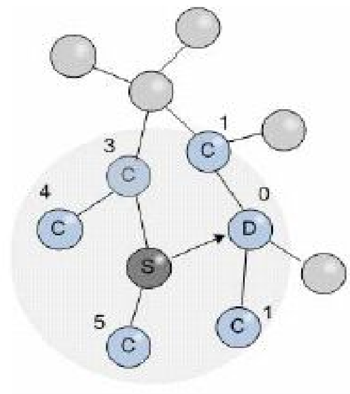

Fig.4. Shortcut Tree Routing

STR With Geographic Location

STR is not always optimal in aspect of end-to-end hop distance. It is because, next hop node is selected based on local information like 1-hop neighbour table. In some cases, there may be more than one neighbour nodes with one hop distance. Sending node will be confused to which neighbour it should forward the data, Each node will keep the geographical information regarding the destination. For ex, if the destination is located at the North side of the network, sending node will send data to the neighbour node in North side, for this we divided the panel into four sections, that is north, south, east and west and we routed the data packets according to the location. This would further reduce the network overhead to a large extend. Hopcount, route cost and memory consumption can also be reduced.

PERFORMANCE EVALUATION

We evaluated STR with geographic location in diverse metrics of the routing performance and overhead. The evaluation of the routing performance includes hop count, route cost, routing overhead and memory consumption for routing. We simulated the proposed system using java.
In this simulation we compared STR based on geographic location with the STR and ZTR algorithms. And zigbee address assignment scheme are applied to the all routing protocols. In order to keep ZigBee's network formation and discovery procedures, we limit the number of children and maximum depth of the tree by setting Cm=4,Rm=4 and Lm=5

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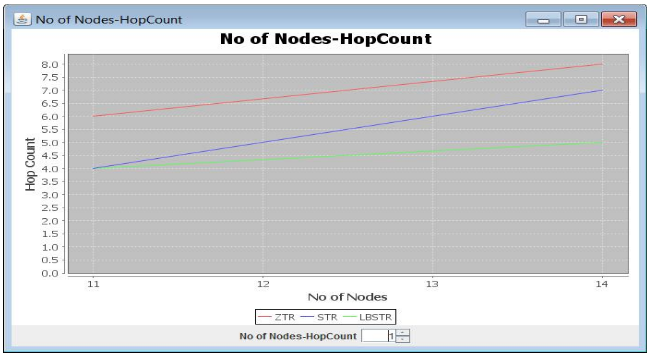

Fig.5. No of Nodes Vs Hopcount Graph

Fig.5 measures the total hop count when all the nodes send the data to the coordinator as the number of nodes grows. As the number of nodes increase, the total hop count also increases. However, the total hop count of our proposed system is much smaller than shortcut tree routing(STR) and ZigBee tree routing(ZTR),the equation for the calculation is, Hop count=(level(S) – highest level of sub-tree) + (level(D) – highest level of sub-tree)

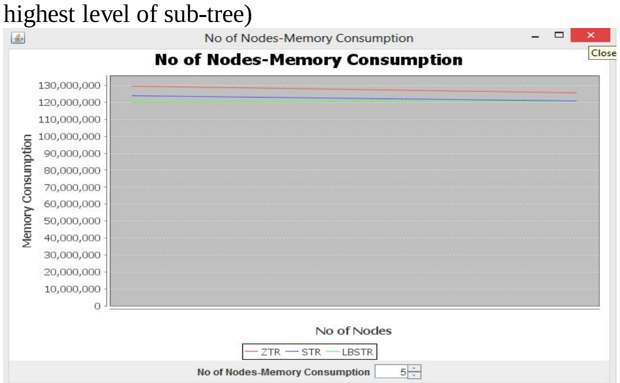

Fig.6. No of Nodes Vs Memory Consumption Graph

Fig.6 describes the total memory consumption for the routing. The memory consumption is comparatively less when compared to STR and ZTR.

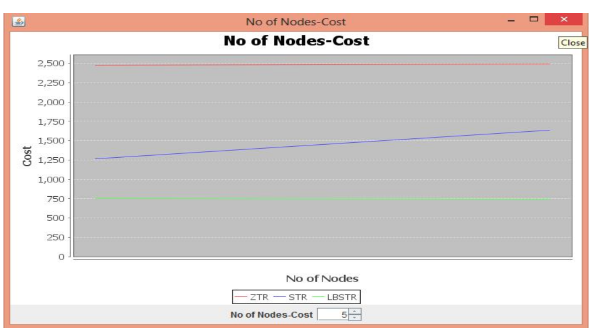

Fig.7. No of Nodes Vs Cost Graph

The evaluation in fig.7 shows that the routing cost of our proposed system is very less when compared to STR and ZTR.The equation is, Route cost=level(S)+level(D)-2.level(LCA(S,D))

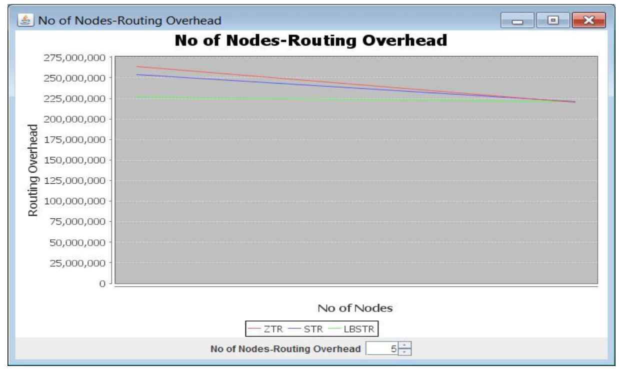

Fig.8. No of Nodes Vs Overhead Graph

Fig.8 shows that the routing overhead is less when compared to STR and ZTR .The routing overhead is calculated using the CPU load.

CONCLUSION

An efficient shortest path routing protocol is proposed.STR will have less overhead and memory consumption. If more than one neighbor node has information of destination node, geographical information will be used to select the next node. Overhead will be reduced further by using geographical information.

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