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Scalable Performance Testing of a ZigBee Protocol for High Data Rate Application

Johnsymol Joy
M. Tech. Student, School of Computer Sciences, Mahatma Gandhi University, Kerala, India
Varghese Paul
Associate Professor, Department of IT, CUSAT, Kerala, India
Shyni S. T.
Assistant Professor, School of Computer Sciences, Mahatma Gandhi University, Kerala, India

Abstract:
ZigBee is a wireless personal area network (WPAN). It works on the standard IEEE 802.15.4. This standard works on the maximum frequency 2.4GHz. While works on this standard ZigBee get a maximum data rate of 250kbps. So usually ZigBee network is used for low data rate application. But with the development of tiny cameras that can be possible to place inside sensor nodes there comes need for sending data that require high data rate like images, videos etc. So in order to increase data rate and thereby increasing global throughput ZigBee uses multipath routing protocols. Hybrid ZMR is one of such multipath routing protocol. It finds multiple paths based on proactive tree routing and reactive AODV routing. While designing an efficient routing protocol scalability is an important factor. This paper checks the scalability of hybrid ZMR protocol and comparing it's scalability with traditional ZigBee tree routing protocol.

Keywords: *Wireless Sensor Networks, IEEE 802.15.4/ZigBee, Tree Routing, Cluster-tree Topology, ZigBee Multipath Routing.*

1. Introduction

ZigBee is a wireless personal area network like bluetooth. Maximum of seven nodes can be connected using Bluetooth. But in the case of ZigBee network, it is possible to connect thousand numbers of nodes within a 100m range. Like bluetooth ZigBee also has ZigBee devices made up of RF transmitter and receiver. ZigBee devices are usually low cost devices and also they are resource constrained devices. Resource constrained means they have limited memory and processing capabilities. ZigBee works on IEEE 802.15.4 standard that works on the frequency 2.4GHZ. Maximum data rate that can be achieved by this ZigBee network is only 250kbps. So at the early stage it is mainly used for low data rate applications. But the development of WMSN's, there comes need for sending data that require high data rate like video, images etc. For that different approaches are used. One of such approach is using multipath routing protocols. ZMR is a multipath routing protocol used in ZigBee network.

A ZigBee network has mainly three components. First one is ZigBee coordinator, it has several duties including initialization, maintaining and controlling the network. Subsequent components are ZigBee router and end devices. ZigBee devices can be of two types FFD (Fully Functional Devices) and reduced functional Devices (RFD). Network topologies supported by the ZigBee network are star and peer-to-peer topology. In star topology all the devices are connected to a center coordinator. In peer-to-peer topology each device can converse with another device that is in the range. Based on the restrictions that a device can communicate with each other, peer-to-peer topology takes different shapes. First one is mesh topology, here no restriction with each other. Second one is tree topology; here a parent-child relationship exists between each node.

Usually single path routing is not efficient for WSNs because of several reasons. Sometimes source node select intermediate nodes of the path from the same part of the network, this will cause power depletion. This will finally result shorter network lifetime. Because of several interferences node failure may result and if the failed node is among the node belongs to the path created by the single path routing this will lead to entire communication failure. Sometimes there occurs the presence of malicious nodes in the path, such nodes may manipulate and corrupt the data without the knowledge of sink node.Multipath routing is a different routing technique, which selects multiple paths to deliver data from source to destination.

Routing protocol can be classified mainly into two based on the method of path creation. They are reactive and proactive. Reactive means, protocols under this category create route only on demand. Proactive type is table driven. Example of reactive type is AODV [4], Adhoc On demand Distance Vector routing protocol. They create path at the time of routing. For path creation it need route discovery and maintenance procedure. For route discovery a source will broadcast a RREQ (route request) packet. Up on accepting

this RREQ packet neighbour node will check, if it is the destination. If not then that node will save the next and node from which it receive the RREQ packet in its route discovery table this is for reverse path creation. Up on reaching the destination, the destination node will send the RREP packet back to the source through the already created reverse path. It will create an optimum path. But the problem is ZigBee devices are resource constrained devices, ie it has less memory and processing capabilities. So this type of devices cannot handle so much routing overhead.

Next come ZTR (ZigBee Tree Routing), a proactive type routing protocol. In this type there should exists a direct path from any node to sink node. There always have a parent-child relationship between any nodes. Using thid parent-child link any node can reach any other node. Here routing overhead can be avoided. But the problem is detour problem. That means it deviates from the original optimum path. For avoiding these problems next comes STR (Short cut Tree Routing). This takes neighbour node from neighbour table as the next node. Routing cost is reduced, if the destination is a neighbour node. These all are single path routing used in ZigBee network. They are usually used for low data rate applications. Next is some Multipath routing protocol used in ZigBee network. First one is ZigBee Hierarchical Tree Routing. It creates multiple paths entirely based on Tree routing. Second one is ZMR (ZigBee Multipath Routing).

2. ZigBee Multipath Routing protocol (ZMR)

ZigBee Multipath routing (ZMR) is called hybrid ZMR because it uses proactive tree routing and reactive AODV routing for multipath creation. Proactive part will be activated first.This is mainly for reducing end-to-end delay. So the first path used should be the direct tree path from source to sink. For finding second path it uses both neighbor table information and the tree path information. Source node chooses next node from the neighbor table that satisfy the node disjoint property. Node disjoint property means, the selected node should not be used by already created path. Sometimes the selected neighbor node may be sink itself, in that case a directed path of on link. Otherwise it may be NTR node. NTR means node belongs to branch of a tree path, i.e. from the NTR node to sink there should be a direct tree path. In that case a path consists of one neighbor node and tree path from NTR node to sink will be established.

For additional path creation, reactive part of the protocol will be activated. Basic idea of reactive part is source will send an Explore Message to next node. While receiving this message the node will check if it is the destination node. If not then it will save the address of the next node and the node from which it receive the message in its route discovery table, this is for creating a reverse path. When the Explore message reach the destination, through the already created reverse path the destination will send back a Response message. When this Response message reach source, a new path will be established by the reactive way. Sometimes an intermediate node does not have a neighbor node to send the Explore message, that case an Error message will be send back to source. When source node get an Error message a new path discovery procedure will be activated.

3. Scalability Study

Scalability is an important factor while considering efficiency of a routing protocol. Scalability of a routing protocol is the capability of a routing protocol [8] to perform efficiently when parameters of the network like the number of nodes (N), the average rate of mobility (M), Node Density (D), number of links (L), frequency of connection establishment (F) etc grow to be large in value. So a network is believed to be scalable with respect to the parameter if and only if, as the parameter increases, the network's minimum traffic load does not increase faster than the network rate can bear. Network rate is the maximum number of bits that can be transmitted at the same time. For scalability checking of ZMR here taking the parameter as number of nodes. While considering scalability, the total routing overhead for a routing protocol should not increase faster than network minimum traffic load. Routing overhead may be proactive routing overhead, reactive routing overhead, sub-optimal routing overhead etc.

4. Implementation and Result

For checking scalability based on the parameter number of nodes, here varying the number of nodes as 21,41,61,81 and 101. Simulation is carried using NS2 [7] simulator. And for each set of nodes performance is checked based on the metrics throughput, packet delivery ratio, residual energy, average end-to-end delay, and drop. Throughput is the total number of packet reached destination successfully. Fig 1 shows how throughput affected when the number of nodes changes from 21 to 101.

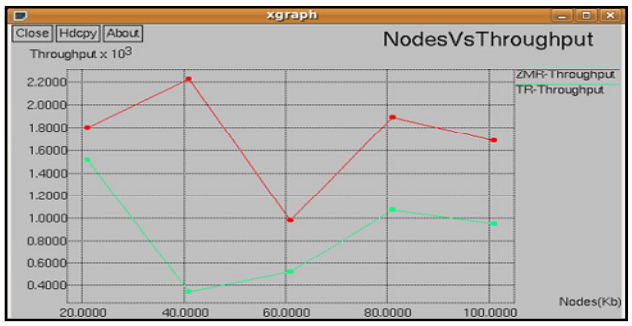

Figure 1: Graph of Nodes Vs Throughput for ZMR and TR

Fig 2 shows how residual energy affected when the number of nodes changes from 21 to 101.

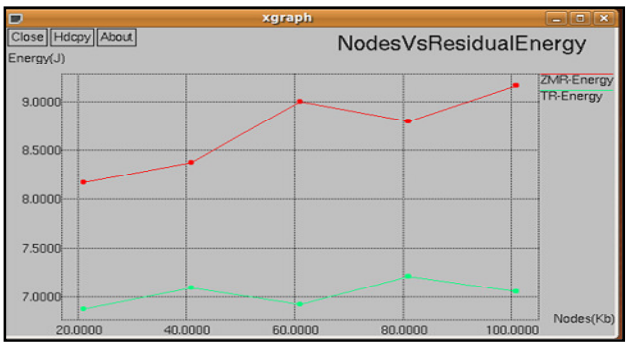

Figure 2: Graph of Nodes Vs Residual Energy for ZMR and TR

Fig 3 shows the packet drop rate when the number of nodes changes from 21 to 101.

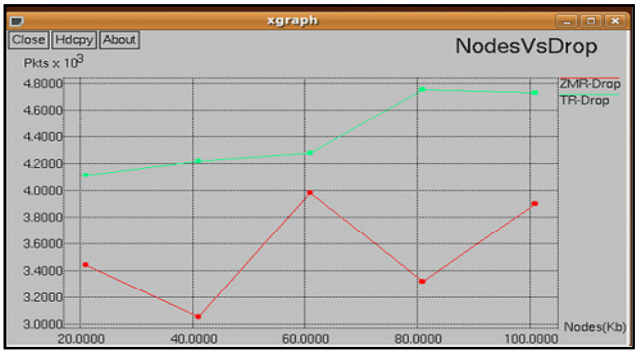

Figure 3: Graph of Nodes Vs Drop for ZMR and TR

Delivery ratio is the ratio of total packet receives to send. Fig 4 shows how delivery ratio affected when the number of nodes changes from 21 to 101.

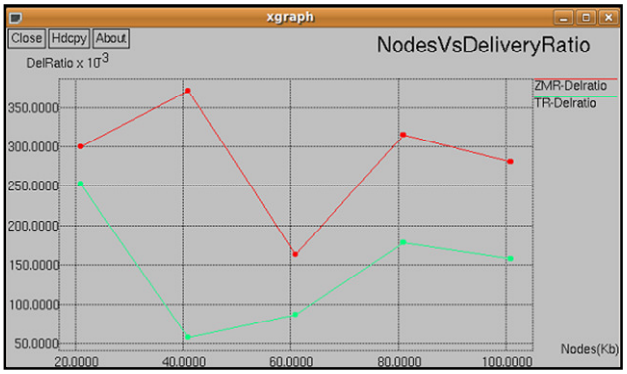

Figure 4: Graph of Nodes Vs Delivery Ratio for ZMR and TR

Fig 5 shows delay when the number of nodes changes from 21 to 101.

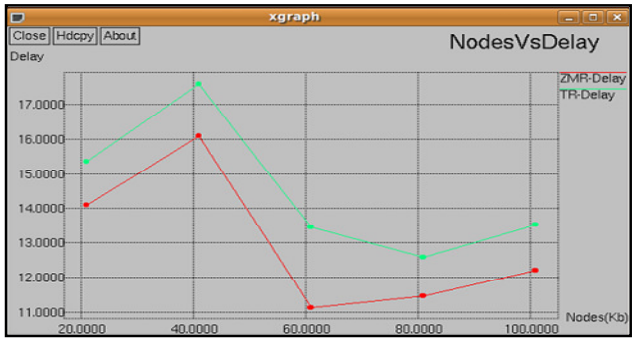

Figure 5: Graph of Nodes Vs Delay for ZMR and TR

While comparing the scalability of the ZMR and tree routing, based on parameter varying number of nodes ZMR is more scalable than tree routing with respect to the metrics throughput, delay, drop, delivery ratio etc.

5. Conclusion and Future Works

ZigBee is a personal area network (PAN) like Bluetooth, initially used for low data rate applications. Now a day's with the development of WMSN, there comes need for sending data that require high bandwidth.ZigBee uses Multipath routing protocol for achieving these requirements. ZMR is a hybrid multipath routing protocol, which uses both proactive tree routing and reactive AODV routing for creating multiple paths. For designing an efficient routing protocol, there are so many factors to be considered. Scalability is one of the main factor should be considered. This paper checks the scalability of ZMR multipath routing protocol. Enhancement on this protocol is making this energy efficient.

6. References

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