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# Performance Comparison of Network Topologies in ZigBee Based WPAN

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**Abstract**— ZigBee is two-way wireless communication standard with low cost and low power consumption, developed by the Zigbee Alliance. Zigbee network based on IEEE 802.15.4 standard offers unique advantages for wireless applications. One of the application areas of Zigbee is focuses short-range wireless data transfer at low data rates. ZigBee networks are successfully employed in areas such as consumer electronics, home and building automation, industrial controls, PC peripherals, medical sensor applications, and entertainment electronics. The comparative performance analysis of star and mesh topologies have been studied and analyzed for ZigBee based networks.

The Network Simulator (NS-2) is one of powerful tool used to simulate wireless networks. The performance of ZigBee based wireless PAN is evaluated by considering Packet Delivery ratio (PDR), Delay, Jitter and Throughput for Star and mesh topologies. Various scenarios are generated by varying number of node on, range, mobility, simulation time and routing protocol for star and mesh topology in Zigbee Network. The performance parameters and graphical results are extracted from the trace files. Simulation results shows that mesh wireless PAN network performs better as compared to star networks, further packet delivery ratio decreases as the deployment area increases.

**Index Terms**— Delivery ratio, Delay, Jitter, Throughput, IEEE 802.15.4, Star topologies, Mesh topologies, NS-2, WPAN, WSN, Zig-bee Wireless networks.

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## 1 INTRODUCTION

IEEE 802.15.4 and ZigBee are protocols that provide the network infrastructure required for wireless sensor network applications. In the recent years, in design of parallel computers, Mesh based interconnection has been utilized extensively. Flow control in interconnection networks has mainly been an issue to prevent buffer overflow and packet loss. Packet loss occurs when one or more packets of data traveling across a network fail to reach their destination. The number of factors including buffer overflow, congestion, corrupted packets rejected in-transit, faulty link, faulty nodes or deadlocks are the some of the reasons for packet loss.In addition to this, packet loss probability is also affected by down of links and distances between the transmitter and receiver

A simulation framework for mesh interconnection network has been designed, where the packet loss during the link down has been analyzed. Analysis and evaluation has been done on mesh interconnection networks on different traffic patterns using simulation on NS2.

The paper is organized into six sections. Section 1 gives Introduction .Section 2 contains ZigBee and IEEE 802.15.4 standard details. Section 3 gives related work. Experimentation details are mentioned in Section 4. Simulation results are presented in Section 5. Section 6 gives the Concluding remarks.

## 2 ZIGBEE AND IEEE 802.15.4 STANDARD

ZigBee is low power consumption, low data rate and low cost technology. Depending on the RF environment and the output power consumption required for a given application, zigbee compliant wireless devices transmit in the range of 10-75 meters and operate in the unlicensed ISM band of 2.4GHz,at data rate 250kbps .

IEEE 802.15.4 is now detailing the specification of PHY and MAC by offering building blocks for different types of networking known as “star, mesh, and cluster tree”.

ZigBee is expected to provide low cost and low power connectivity for equipment that needs battery life as long as several months to several years but does not require data transfer rates as high as those enabled by Bluetooth. ZigBee can be implemented in mesh networks larger than is possible with Bluetooth. The various network topologies supported by ZigBee based networks are Star Topology, Peer-to-Peer Topology and Cluster-tree Topology .

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## 3 RELATED WORK

NS-2 is used to construct the topology and generate different traffic scenarios using an exponential traffic generator. Packets are sent at a fixed rate during ON periods, and no packets are sent during OFF periods. Using this traffic generator, common network performance metrics such as drop probability, packet delay, throughput and communication load are analyzed against different buffer sizes and traffic injection rates.

In [1] Author has mentioned various implementation aspects of ZigBee PRO.The performance of ZigBee PRO is evaluated by data on a ZigBee PRO mesh network for point to point multihop transmission using ZigBee PRO ZB modules. Maximum throughput and latency had been evaluated. Author concludes that ZigBee mesh routing with the necessity of multiple hops results in undesirable performance, alternatively many to one routing may provide better result.

In [2] Author has evaluated the performance of WSN for different terrain areas and different node speed considering Adhoc topology AODV routing. Author concludes that implementation of sensor nodes in small terrain areas gives better performance than large terrain areas.

In [3] Author has analyzed the packet loss in mesh network with source routing. The author concludes that mesh network with the traffic agent which uses acknowledgement mechanism is more reliable. But due to transmission delay link down will be occure.By considering more than one parallel communication at the same time using the same path with the same common nodes in the grid network can be implemented as a future scope.

## 4 EXPERIMENTATION

The experimentation is carried out by preparing simulation model of the ZigBee & IEEE 802.15.4 using NS-2 (Network Simulator – 2).

To automate the simulation process several scripts have to be written. Different scenarios are generated by varying the deployment areas and number of nodes. As the simulation involves star network with the coordinator always being the destination AODV routing broadcast are not required. By varying required parameters over the required range, the script run the simulation scenarios. After that it performs the required data analysis to determine packet delivery ratio. Desired metrics are extracted from NS-2 trace files

To evaluate the performance of the mesh interconnection networks, a simulation model has been developed in NS2 with only built-in options. Tcl is used for specifying the Mesh interconnection network simulation model and running the simulation. The AODV routing algorithm is used to find the path.

### 4.1 SIMULATION ENVIRONMENT

A detailed event driven simulator is developed. This simulator models a 16-node 2-D mesh (4x4) in which routing decisions are taken at source node using source routing methodology. Each node is connected with point-to-point bidirectional serial links.Fig1 shows the simulation interconnection architecture model 4x4 mesh of switches.

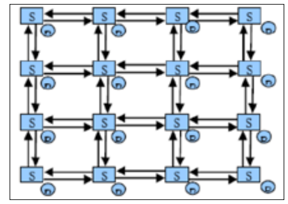

Fig 1. 4X4 Mesh Architecture [3]

Switches consists a slot for a resource. A resource may be a processor core, a memory block, an FPGA, a custom hardware block or any other peripheral devices, which fits into the available slot and compiles with the interface with the network. Here assumption is made that the switches in network have buffers to manage data traffic. Fig1. shows the architecture of simulation model with 16 nodes where connection of switches (S) and resources (R) are shown.

### 4.2 TOPOLOGY

A 4 x 4 two-dimensional mesh topology is modeled and simulated using network simulator NS2. This topology is easily scaled to different sizes. Different resources have their unique communication addresses, so here assumed that all switches has attached processor core as resources therefore treated similarly except that a traffic generator can be attached to resources. The topology has three basic elements which are switch, resource and link. Simulation model assumes that the each resources has infinite buffer size but finite in switches. It means that the packet being dropped or lost cannot occur in resources but only takes place in switches.

### 4.3 COMMUNICATION LINKS

An inter-communication path between the switches is composed of links. Each node is connected with point-to-point bidirectional links. The bandwidth and latency of the link is configurable. When any link is down between two nodes it implies that the packet cannot travel between these nodes in any direction. This assumption is made and is realistic, because bidirectional links are actually implemented by using a single wire.

### 4.4 ROUTING

An inter-communication path is composed of set of links identified by the routing strategy. This simulator models a 16-node 2-D mesh (4x4) in which routing decision is taken at source node using AODV routing methodology. The Fig2. shows 2D 4X4 Mesh WPAN in NS-2.

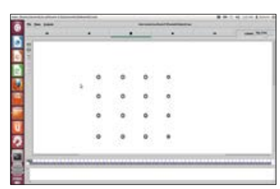

Fig 2 .4X4 Mesh WPAN in NS-2

The Fig 3. shows the network topology of star WPAN with 16 nodes in NS-2

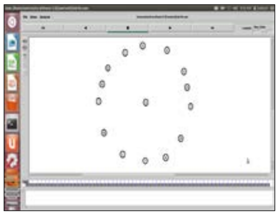

Fig 3. Star WPAN with 16 nodes in NS-2

## 5 Simulation Results

The performance parameters packet delivery ratio & packet loss ratio had been calculated by using Network Simulator-2, for different number of nodes and different areas for wireless star networks as shown in the table1and table 3.Table2.and Table 4 gives simulation results for mesh topology for different number of nodes and different areas

TABLE 1
Simulation Results of star WPAN(9 nodes)

| Star Results | (9NODES) | | |
|---|---|---|---|
| Area | small | medium | large |
| Packet sent | 38310 | 1820 | 1820 |
| Packet received | 37548 | 654 | 107 |
| loss | 762 | 1166 | 1713 |
| LR | 1.989036805 | 64.06593407 | 94.12087912 |

The simulation results show that as the deployment area increases, the delivery ratio decreases and the packet loss ratio increases.

TABLE 2
Simulation results of 2D 3X3 Mesh WPAN

| 2D 3X3Mesh Results | | | |
|---|---|---|---|
| Area | small | medium | large |
| Packet sent | 39269 | 26582 | 1820 |
| Packet receive | 36362 | 23864 | 0 |
| loss | 2907 | 2718 | 1820 |
| LR | 7.402785913 | 10.22496426 | 100 |

TABLE 3
Simulation results of star WPAN(25 nodes)

| Star Results | (25NODES) | | |
|---|---|---|---|
| Area | small | medium | large |
| Packet sent | 1820 | 1820 | 1820 |
| Packet received | 1755 | 711 | 653 |
| loss | 65 | 1109 | 1167 |
| LR | 3.571428571 | 60.93406593 | 64.12087912 |

TABLE 4
Simulation results of 2D 5X5 Mesh WPAN

| 2D 5X5Mesh Results | | | |
|---|---|---|---|
| Area | small | medium | large |
| Packet sent | 36691 | 39550 | 39555 |
| Packet receive | 36165 | 35968 | 35416 |
| loss | 526 | 3582 | 4139 |
| LR | 1.433594069 | 9.056890013 | 10.46391101 |

The performances of star and mesh WPAN varying number of nodes and deployment area from small, medium to large can be represented graphically.
The fig 4. shows integrated performance of WPAN with different number of nodes & different deployment areas. Mesh topology gives better performance as the number of nodes increases. Performance decreases as the deployment area increases for both the topologies due to restricted range of nodes.

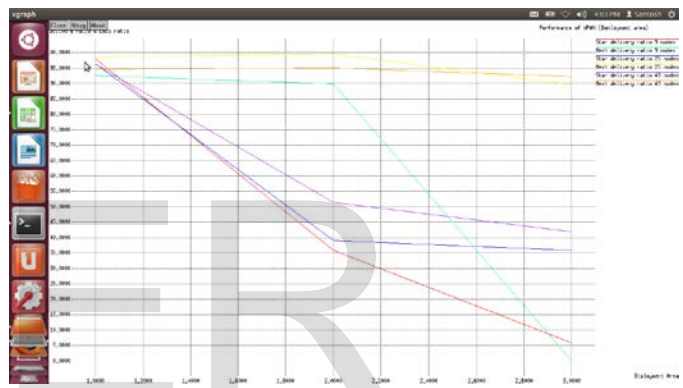

Fig 4. Performance of WPAN (deployment area)

The Fig 5. shows the integrated performance of WPAN (Mobility) for 9, 25 & 49 nodes.

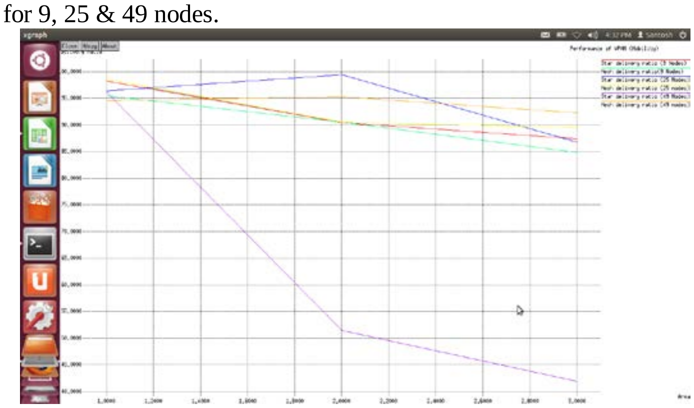

Fig 5 Performance of WPAN (Mobiliy)

Results show that mesh network proves good for PDR than star networks for medium and large deployments. While considering mobility for 9 nodes star gives better performance than mesh .It gives approximately same packet delivery ratio for star and mesh for medium area further delivery ratio declines for large network.
The performance of WPAN (9 nodes) with variable range as well as deployment area is presented in fig.6 The range of node is changed from 5, 10 to 15meters.Star WPAN gives better PDR for 5-10 m range than mesh WPAN. For large (15m) & medium (10m) deploy-

ment area network mesh WPAN gives better packet delivery ratio than star .

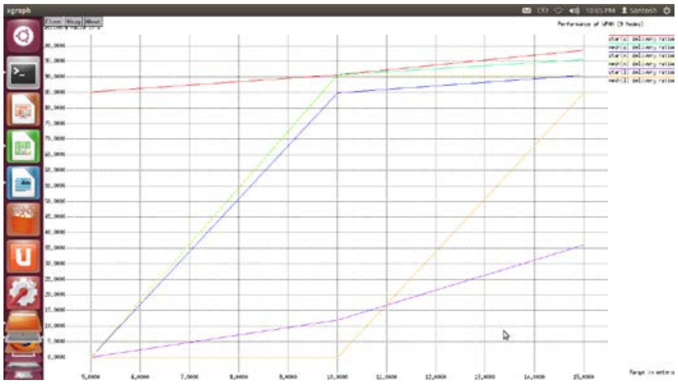

Fig 6. Performance of WPAN (Range 9 nodes)

The fig7. shows the performance of WPAN (Range 25 nodes) varying the range as well as deployment area. The range of node increases the performance also increases in case of both the star and mesh topologies.

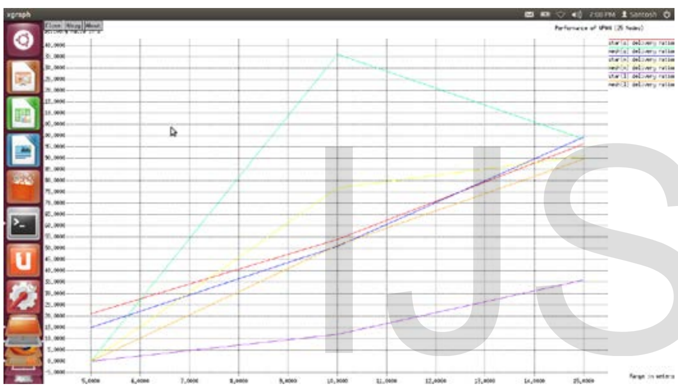

Fig 7. Performance of WPAN (Range 25 nodes)

The Fig 8 shows the performance of WPAN (Range 49 nodes) varying the range. The range of node increases the performance also increases. For the range 15m both the star and mesh topologies gives improved PDR .

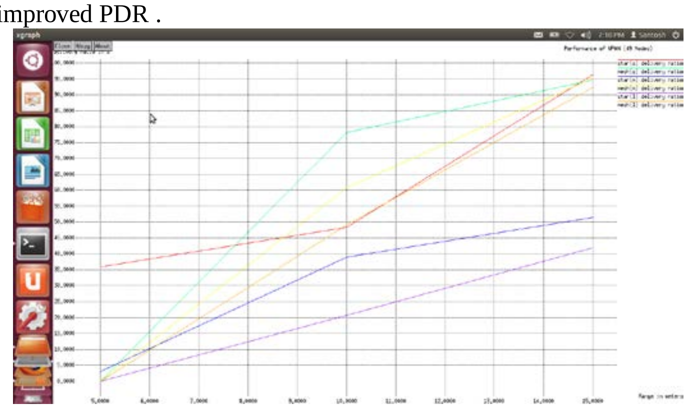

Fig 8. Performance of WPAN (Range 49 nodes)

## 6 Conclusions

The zigbee modules have been exclusively tested for the simulator environment. The performance parameters for the Zigbee star wireless network and mesh network had been compared by using network Simulator-2 (NS-2).This work has considered the following situations varying the deployment area from small to large and number of nodes from 9, 25 and 49 for star and mesh WPAN.The performance of zigbee network is evaluated by considering packet delivery ratio by varying the parameters like range, mobility, deployment area .The Zigbee mesh topology gives better performance as the number of nodes increases under the highly mobile environment than star topology. Due to the multihop transmissions, routing options are available. As the scalability and number of nodes increases, because of the congestion and interference PDR decreases rapidly for the medium and large deployment area networks and end to end delay will be increased this in turn affects throughput.

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## References

[1] Jianliang Zheng, Myung J. Lee,“A comprehensive performance study of IEEE802.15.4”http:// www.ee.ccny.cuny.edu/zheng /papers /paper1 _wpan_performance.pdf

[2] Lalit Kishore Arora, Rajkumar,“Simulation and Analysis of Packet loss in Mesh Interconnection Network with Source Routing” Vol. 2, Issue 6, June 2012 ISSN: 2277 128X International Journal of Advanced Research in Computer Science and Software Engineering

[3] Vaddina Prakash Rao,” The simulative Investigation of Zigbee/IEEE 802.15.4”,http://www.vaddina.com/pages/01_01_00_00_Zigbee/00_content/zigbee.pdf

[4] Jae Chung and Mark Claypool, “NS by Example”,http://web.uettaxila.edu.pk /CMS/seISOPNbsSp09/tutorial/nsbyExamples.pdf

[5] Yinfei Pan, Department of Computer Science, “Design Routing Protocol Performance Comparison in NS2: AODV comparing to DSR” www.cs.binghamton.edu/~kang/teaching/cs580s.../yinfei-final.pdf

[6] Ling-xi Wu, Jie Zhan, Wei Shi. "The Low Power Study Based on Zigbee Network". *4th International Conference on Wireless Communications, Networking and Mobile Computing, WiCOM 2008*. IEEE. p.1-4.

[7] Daintree (2010),“Getting Started with ZigBee and IEEE 802.15.4”, [Online].Available:http://www.daintree.net/downloads/whitepapers/ZigBee_primer.pdf

[8] Chen Zhijia, Lin Chuang, Wen Hao, Yin Hao. "An Analytical Model for Evaluating IEEE 802.15.4 CSMA/CA Protocol in Low-Rate Wireless Application". *21st International Conference on Advanced Information Networking and Applications Workshops*.IEEE, 2007. p. 899-904.

[9] Raoulvan Bergen, “ZigBee Mesh Networking” ,Digi International

[10] Singh Chandramani Kishore, Kumar Anurag, AmeerP.M, “Perform ance evaluation of an IEEE 802.15.4 sensor network with a star topol ogy”.Wireless Networks.2007;vo.l14, no.4 p. 543-568