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Performance Analysis of IEEE 802.15.4/ZigBee Wireless Sensor Networks

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Abstract

Wireless sensor networks are becoming very popular from daily life to environmental monitoring, agriculture, health care, home automation and many more. The survey on these types of networks showed that, the deployment of such sensor networks has dramatically improved in recent years and will boost in the future due to the release of two standards by IEEE and ZigBee Alliance, named as IEEE 802.15.4 standard and ZigBee standard respectively. This is because ZigBee is the only unique standard developed for low-power, a low-cost, low-data rate based wireless technology network, that provides network security, and application support services operating on top of the IEEE 802.15.4 Medium Access Control (MAC) and Physical (PHY) Layer wireless standard. Therefore, it will be beneficial to study the performance of IEEE 802.15.4/ZigBee sensor networks so that, various solutions can be introduced to improve the quality of such networks. In this paper, the analysis of IEEE 802.15.4/ZigBee network has been done by using throughput and energy remaining per node as the performance metrics. The simulations are done in Network Simulator 2, which is an object oriented network simulating tool.

Keyowrds : ZigBee, throughput, IEEE 802.15.4

Introduction

A wireless sensor network consists of a number of sensor nodes which are deployed inside or close to the area, where the parameters to be measured. Different wireless technologies can be used for different node communication like IEEE 802.11 WLANs, WPANs, Bluetooth etc. But most of the applications are of low power , low range and low data rate. IEEE 802.15.4 is the approved low-rate standard for a simple, short-range wireless network whose radio components could run several years on a single battery. The low rate (LR) wireless personal access network (WPAN) (IEEE 802.15.4/LRWPAN) is intended to serve a set of industrial, residential, and medical applications with very low power consumption, low cost requirement, and relaxed needs for data rate and QoS [6].

ZigBee technology is such a low data rate, low power, low cost, wireless networking type, particularly for automation and remote control applications. The IEEE 802.15.4 committee and ZigBee Alliance together developed the technology, known as ZigBee. It is expected to provide low-cost and low-power connectivity for devices that need battery life as long as several months to several years but does not require high data transfer rates like in Bluetooth. ZigBee can be implemented in mesh networks and can operate in the unlicensed RF worldwide (2.4 GHz global, 915 MHz America, or 868 MHz Europe) bands. The data rate is 250 kbps at 2.4 GHz, 40 kbps at 915 MHz, and 20 kbps at 868 MHz [7].

Routing Protocols

Routing protocols can be classified as either (i) **table-driven** or **proactive** protocols, which are “conservative” protocols in that they do try to keep accurate information in their routing tables, or (ii) **on demand** protocols, which do not attempt to maintain routing tables at all times but only construct them when a packet is to be sent to a destination for which no routing information is available. Examples for table-driven protocols are Destination-Sequenced Distance Vector (DSDV)[3], Cluster head Gateway Switch Routing (CGSR)[1] , and Wireless Routing Protocol (WRP) [5]. Popular on-demand protocols are Dynamic Source Routing (DSR) [4], AODV [2] etc.

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Network Simulator Tool

Network Simulator (Version 2), widely known as NS2, is simply an event driven simulation tool that has proved useful in studying the dynamic nature of communication networks [8]. Simulation of wired as well as wireless network functions and protocols (e.g., routing algorithms, TCP, UDP) can be done using NS2. In general, NS2 provides users with a way of specifying such network protocols and simulating their corresponding behavior. It implements different network protocols (TCP, UDP), traffic sources (FTP, web, CBR, Exponential on/off), queue management mechanisms (RED, Drop Tail), routing protocols (Dijkstra) etc. It is an object oriented simulator written in OTcl and C++ languages. While OTcl acts as the frontend (i.e., user interface), C++ acts as the backend running the actual simulation.

After simulation, NS2 outputs either text-based or animation-based simulation results. To interpret these results graphically and interactively, tools such as NAM (Network AniMator) and XGraph are used. To analyze a particular behavior of the network, users can extract a relevant subset of text-based data and transform it to a more conceivable presentation.

In this paper, the performance evaluation is done using NS 2 network simulator. The network performance of IEEE 802.15.4/ZigBee network is analyzed with the performance metrics as throughput and energy consumption per node. The performance evaluation of IEEE 802.15.4 standard is done for AODV and DSDV protocols. The performance analysis of clustered and non clustered networks has also been done.

Simulation Parameters

Table 1: Simulation Parameters for IEEE 802.15.4/ZigBee network

PARAMETERS	
Channel Type	Wireless Channel
Radio propagation model	TwoRayGround
MAC Type	MAC 802_15_4
Antenna Model	OmniAntenna
Number of nodes	15
Protocol Type	AODV/DSDV
Dimension of topography	100m*100m
Interface queue	Queue/DropTail/PriQueue
LL type	LinkLayer

Simulation Results and Analysis

a) An IEEE 802.15.4/Zigbee Network With AODV And DSDV Protocol

i) Throughput comparison

A ZigBee network with 15 nodes has been set up. Node 0 is considered as the sink and node 10 as the source. The network is simulated using both AODV and DSDV protocols for varying data rates ranging from 50bps to 150Mbps. The NAM window for simulated ZigBee network is shown in Figure1. The throughput obtained for both the protocols is shown in Table2 and plotted in Figure2.

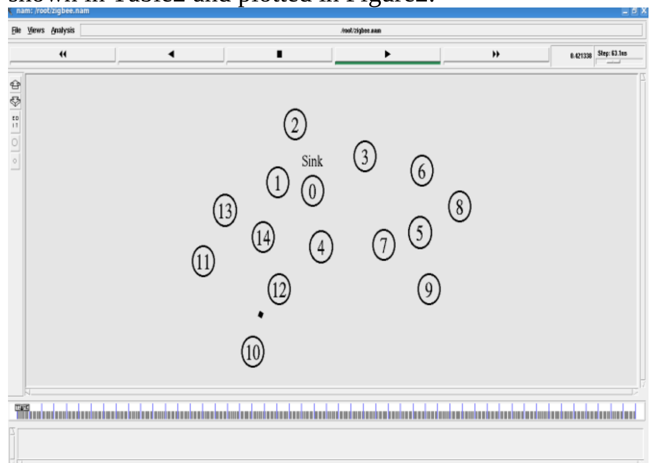

Figure 1: NAM Windows for a ZigBee Network

Table2: Throughput for Different Data Rates

Rate (bps)	Throughput (kbps)	
	AODV	DSDV
50	318.7	1106.56
100	318.7	1106.56
1000	2135.04	1909.12
50000	98552.32	46435.84
100000	196929.28	10306.56
250000	492224.63	231115.52
500000	984275.84	462203.52
1000000	1968407.04	836619.52
10000000	2962160.64	1361221.12
50000000	2962160.64	1161536.63
100000000	2962160.64	2113528.95
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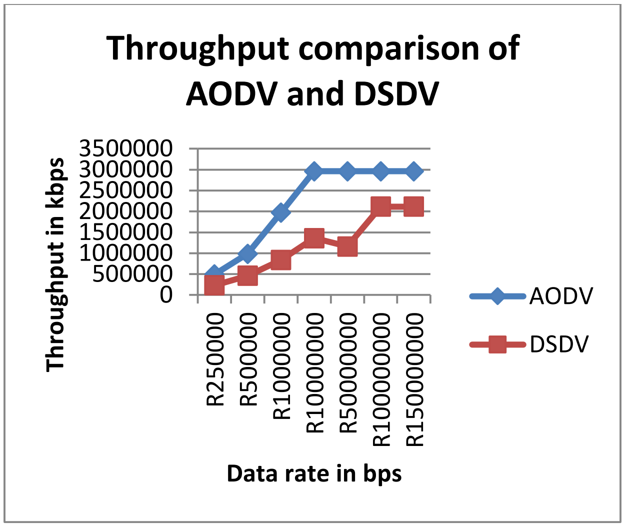

Figure 2 : Throughput for Different Data Rates

From the graph we can see that as the data rate increases the throughput also increases for both AODV and DSDV protocols. As data rate increases, we can see that AODV becomes more reliable because of its reactive nature i.e., its on-demand protocol unlike DSDV which is proactive/table driven protocol. In DSDV as data rate increases, network congestion occurs due to high traffic in the network because of increase in overhead and control messages for routing updations. Therefore, we can conclude that AODV performs much better than DSDV in ZigBee networks.

ii) Remaining Energy comparison

The energy remaining at each node is found out for the same network with AODV and DSDV protocols. The result obtained is given in Table 3 and is analyzed using Figure 3.

Table 3: Remaining Energy Per Node for AODV and DSDV

Nodes	Remaining energy (%)	
	AODV	DSDV
no	99.99821	99.9962492
n1	99.99851	99.9963113
n2	99.99849	99.9963894
n3	99.99851	99.996401
n4	99.99843	99.9963237
n5	99.99849	99.9963773
n6	99.99844	99.9963592
n7	99.99851	99.9964603
n8	99.99846	99.996341
n9	99.99843	99.9963995
n10	99.99784	99.9963124
n11	99.99843	99.996349
n12	99.99841	99.9964746
n13	99.99843	99.9963639
n14	99.9984	99.9963993

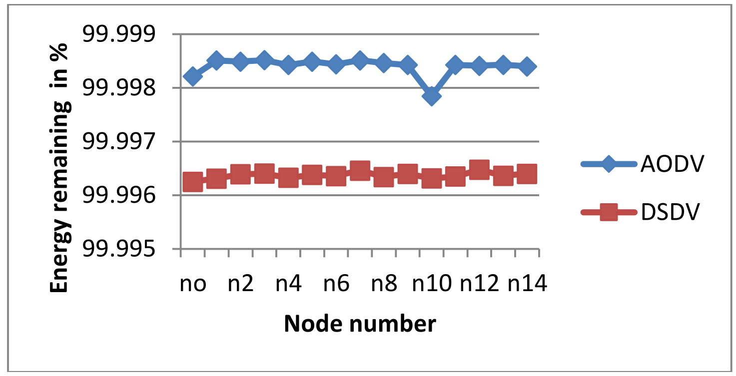

Figure 3: Energy Comparison at Each Node

Comparing both the protocols using graph, it is seen that AODV consumes much less energy than DSDV, or we can see that remaining energy for AODV is greater than DSDV. This is because since DSDV is table driven, the nodes always consume energy for routing table updations even when there is no traffic. But AODV consumes energy only during traffic. In the graph we can see that the remaining energy is less for node 0 and node 10. This is because out of the 15 nodes, node 0 is the sink and node 10 is the source.

b) A Zigbee Network With Non-Clustered And Clustered Topology

In the first case, a non-clustered network is set up with node 13 as the source and node 8 as the sink. The protocol used is AODV and the network is shown in figure 4. The transmitted power for each node is varied from 0.1 mW to 1 W and its corresponding throughput is measured.

In the second case, a clustered network is set up as shown in figure 5. The entire network is divided in to three clusters with nodes 10, 11, 12, 13, 14 as cluster 1 and nodes 0, 1, 2, 3, 4 as cluster 2 and nodes 5, 6, 7, 8, 9 as cluster 3. Now, the node 13 is considered as source and node 8 as the sink. Since the source and sink are in different clusters, the data is routed through the cluster leaders. i.e., data flow is from node 13 to node12 (cluster head of cluster1), then from node 12 to node 0(cluster head of cluster2) and from node 0 to node 5 (cluster head of cluster3) and finally from node 15 to sink node 8. The throughput for various transmitted power of each node (0.1mW to 1W) is measured. The obtained results of both the networks is given in Table 4 and are compared using figure 6.

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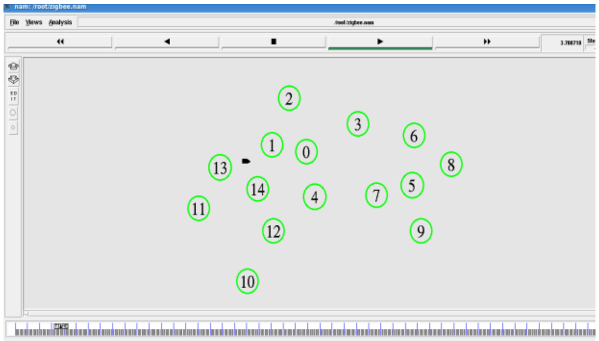

Figure 4 A Non-clustered ZigBee Network

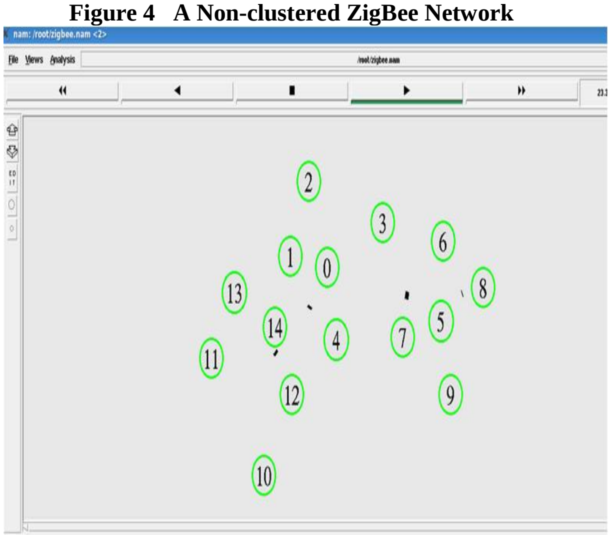

Figure 5: A Clustered ZigBee Network

Table 4: Throughput Comparison of Clustered and Non-Clustered Network

Transmit Power (Watts)	Throughput (kbps)	
	Clustered network	Non-Clustered network
P0.0001	0	0
P0.001	57967.99	0
P0.01	53490.87	0
P0.05	32507.84	73247.36
P0.1	32342.71	73247.36
P0.3	32342.71	73247.36
P0.5	32342.71	73247.36
P0.7	32342.71	73247.36
P1	32342.71	73247.36

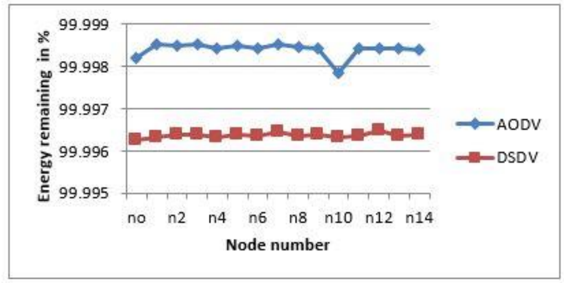

Figure 6 : Comparison of Non-Clustered and Clustered Topology

From figure 6, we can analyze that a minimum of 0.01 W of power is required for reliable data transfer in non-clustered network. When clustering is used, the transmit power of source node can be reduced since the data flow occurs through cluster heads.

From the above simulation results, we can see that the ZigBee network performs better with AODV protocol in terms of both throughput and energy consumption. From the second case, we can conclude that if clustering is used, the transmitted power required for each node can be reduced.

Conclusion

In this paper we have discussed on the importance of IEEE 802.15.4/ZigBee sensor networks. Various simulations has also been done to analyse the performance of the network based on throughput and energy consumption per node. From the simulation results, we can conclude that the ZigBee network performs better with AODV protocol in terms of both throughput and energy consumption. From the second case, we can infer that if clustering is used, the transmitted power required for each node is low, which is the major factor for an energy efficient network.

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