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Wireless Network Topological Routing In Wireless Sensor Networks

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Abstract

Wireless Sensor Networks (WSNs) consist of thousands of tiny nodes having the capability of sensing, computation, and wireless communications. Many routing, power management, and data dissemination protocols have been specifically designed for WSNs where energy consumption is an essential design issues. Since wireless sensor network protocols are application specific, so the focus has been given to the routing protocols that might differ depending on the application and network architecture. The study of various routing protocols for sensor networks presents a classification for the various approaches pursued. The three main categories explored are data-centric, hierarchical and location-based. Each of the routing schemes and algorithms has the common objective of trying to get better throughput and to extend the lifetime of the sensor network.

A comparison has been made between two routing protocols, Flooding and Directed Diffusion, on the basis of throughput and lifetime of the network. Simulation of AODV (WPAN) is also carried over two topologies with same source and destination node.

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Keywords: Wireless Sensor Networks, Flooding, Directed Diffusion, AODV.

1. Introduction

The popularity of laptops, cell phones, PDAs, GPS devices, RFID, and intelligent computing devices is

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increasing day-by-day. This made the things cheaper, more mobile, more distributed, and more pervasive in daily life. Now, it is possible to construct a wallet size embedded system with the equivalent capability of a PC. Such embedded systems can be supported with scaled down Windows or Linux operating systems. In this scenario, the emergence of wireless sensor networks (WSNs) is essentially toward the miniaturization and ubiquity of computing devices. Sensor networks are composed of thousands of resource constrained sensor nodes and also some resourced base stations are there. All nodes in a network communicate with each other via wireless communication. Moreover, the energy required to transmit a message is about twice as great as the energy needed to receive the same message. On the other hand, using a long route composed of many sensor nodes can significantly increase the network delay. At the same time, always choosing the shortest path might result in lowest energy consumption and lowest network delay. Finally, the routing objectives are tailored by the application; e.g., real-time applications require minimal network delay, while applications performing statistical computations may require maximized network lifetime. Hence, different routing mechanisms have been proposed for different applications. These routing mechanisms primarily differ in terms of routing objectives and routing techniques, where the techniques are mainly influenced by the network characteristics

1.1 Back Ground Work

Routing is a process of determining a path between source and destination upon request of data transmission. In WSNs, the layer that is mainly used to implement the routing of the incoming data is called as network layer. When the sink is far away from the source or not in the range of source node, multi-hop technique is followed. So, intermediate sensor nodes have to relay their packets. The implementation of routing tables gives the solution.In flooding [6], the source node floods all events to every node in the network. Whenever a sensor receives a data message, it keeps a copy of the message and forwards the message to every one of its neighboring sensors and the cycle repeats.Direct Diffusion [8, 21] is the data centric protocol. It is the first proposed protocol for the wireless sensor network scenarios. If directed diffusion does not perform better than flooding, it cannot be considered viable for sensor networks. It consists of several elements: interests, data messages, gradients, and reinforcements.

When a node receives an interest, it checks if the interest exists in the cache. If no matching interest exists *i.e.*, the interest is distinct; the node creates an interest entry and determines each field of the interest entry from the received interest. This entry contains a single gradient toward the neighbour from which the interest was received, with the specified event data rate. Thus, it is necessary to distinguish individual neighbours. Any locally unique neighbour identifier like an IEEE 802.11 MAC address [10], a Bluetooth cluster address [11], a random, ephemeral transaction identifier may be applicable. If there is the matching interest entry, but no gradient for the sender of the interest, the node adds a gradient toward that neighbour and updates the timestamp and duration fields appropriately. It is mainly used for ad-hoc networks. In March 1999, the IEEE established the 802.15 [14, 15] working group as part of the IEEE Computer Society's 802 Local and Metropolitan Area Standards Committee. The 802.15 working group was established with the specific purpose of developing standards for short distance wireless networks, otherwise known as wireless personal area networks (WPANs). When two nodes want to send data at the same time, CSMA-CA [16, 17] comes into play. It gives the solution of hidden node problem in CSMA-CD, in which a node cannot detect another node that also wants to transmit packet resulting a collision. CSMA-CA protocol uses four-way handshake.

1.2 Problem Statement and Objective

Most current WSN routing protocols assume that the wireless network in benign and every node in the network strictly follow the routing behavior and is willing to forward packets to/for other nodes. Most of these protocols cope well with the dynamically changing topology. However, they do not address the problems when misbehavior nodes are present in the network.

A commonly observed misbehaviour is packet dropping. Practically, in a WSN, most devices have limited computing and battery power while packet forwarding consumes a lot of such resources. The design of routing protocols for WSN's must consider the power and resource limitation of the network nodes, the time varying

quality of wireless channels and possibility of packet loss and delay. To address these design requirements several design strategies for WSN's have been proposed. AODV, Flooding and directed diffusion are some of the common protocols. Each having its fair share of advantages and limitations.The main advantage of flooding is the increased reliability provided by this routing method. Since the message will be sent at least once to every host it is almost guaranteed to reach its destination. There are several disadvantages with this approach to routing. It is very wasteful in terms of the networks total bandwidth. While a message may only have one destination it has to be sent to every host. This increases the maximum load placed upon the network. Messages can also become duplicated in the network further increasing the load on the networks bandwidth as well as requiring an increase in processing complexity to disregard duplicate messages.Directed Diffusion uses a naming scheme for the data to save energy. The main disadvantage of directed diffusion is that it cannot be used for continuous data delivery (e.g., environmental monitoring) or event-driven applications. There is limited memory storage for data caching inside the sensor node. Therefore, data aggregation maybe affected.
The IEEE 802.15.4 standard defines the characteristics of the physical and MAC layers for Low-Rate Wireless Personal Area Networks (LR-WPAN). The advantages of an LR-WPAN are ease of installation, reliable data transfer, short-range operation, extremely low cost, use of unlicensed radio bands (ISM band), flexible and extendable networks, integrated intelligence for network set-up and message routing, and a reasonable battery life, while maintaining a simple and flexible protocol stack.

AODV expects/requires that the nodes in the broadcast medium can detect each other's broadcasts. AODV is a reactive routing protocol. This means that AODV does not discover a route until a flow is initiated. This route discovery latency result can be high in large-scale mesh networks.

1.3 Objective and Sub-Tasks

In order to improve throughput in WSN, routing algorithm should be chosen carefully. The throughput of different routing protocols with different topologies has been evaluated with different simulation time. The primary objective of this paper is to improve the throughput in WSNs which is achieved by the following manner:
To analyze, implement and evaluate Flooding protocol.

To analyze, implement and evaluate the directed diffusion protocol. A comparison is being performed between the two protocols.

Performance of AODV protocol using WPAN is evaluated. In order to evaluate the performance of the network, the throughput with different topologies was analyzed.

1.4 Simulation and Design (Fedora Core 4 (8))

Fedora Core [43] is a free operating system base on Linux. Red Hat being developed by the open source community and the Red Hat engineers sponsor the development of Fedora. Fedora Core 4 (FC4) and FC8 are the release of the Fedora Project. Some primary features of FC4 are extensive performance improvements, support for Intel-based Macs and a new Graphical User Interface (GUI) virtualization manager.

The Network Simulator (NS2)
Simulation can be defined as "Imitating or estimating how events might occur in a real situation". It can involve complex mathematical modelling, role playing without the aid of technology, or combinations. The value lies in the pacing you under realistic conditions that change as a result of behaviour of others involved, so you cannot anticipate the sequence of events or the final outcome.

NS2 Overview

NS [45] is an event driven network simulator developed at University of California at Berkeley, USA, as a

REAL network simulator projects in 1989 and was developed at with cooperation of several organizations. Now, it is a VINT project supported by DARPA. NS is not a finished tool that can manage all kinds of network model. It is actually still an on-going effort of research and development. The users are responsible to verify that their network model simulation does not contain any bugs and the community should share their discovery with all. There is a manual called NS manual for user guidance.

NS is a discrete event network simulator where the timing of events is maintained by a scheduler and able to simulate various types of network such as LAN and WPAN according to the programming scripts written by the user. Besides that, it also implements variety of applications, protocols such as TCP and UDP, network elements such as signal strength, traffic models such as FTP and CBR, router queue management mechanisms such as Drop Tail and many more.

There are two languages used in NS2 C++ and OTcl (an object oriented extension of Tcl). The compiled C++ programming hierarchy makes the simulation efficient and execution times faster. The OTcl script which written by the users the network models with their own specific topology, protocols and all requirements need. The form of output produce by the simulator also can be set using OTcl. The OTcl script is written which creating an event scheduler objects and network component object with network setup helping modules. The simulation results produce after running the scripts can be use either for simulation analysis or as an input to graphical software called Network Animation (NAM).

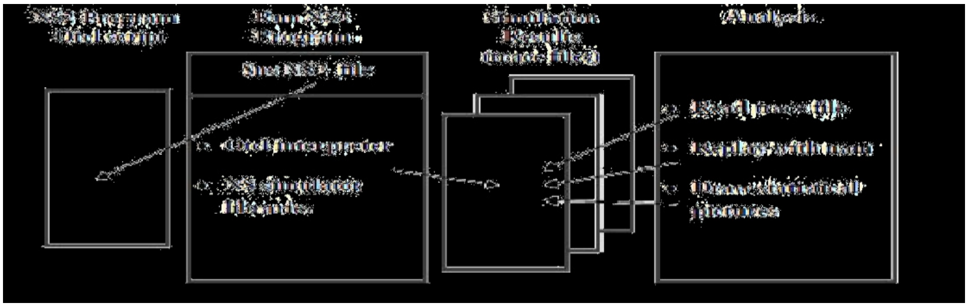

Fig1: Running NS2 Program

NS2 is an event driven network simulator, which can be implemented in Linux-based platform. This report will explain on how to install NS2 in Fedora Core platform. most preferred is inside the computer itself where the NS2 is going to be installed. Since, we are using NS 2.29. It is not recommend logging in as a root because installation at root may interfere with any important Linux files.

Tool Command Language (Tcl)

Short for Tool Command Language, Tcl [46] is a powerful interpreted programming language developed by John Ouster out at the University of California, Berkeley. Tcl is a very powerful and dynamic programming language. It has a wide range of usage, including web and desktop applications, networking, administration, testing etc. Tcl is a truly cross platform, easily deployed and highly extensible. The most significant advantage of Tcl language is that it is fully compatible with the C programming language and Tcl libraries can be interoperated directly into C programs.

The Network Animation (NAM)

The network animator began in 1990 as a simple tool for animating packet trace data. This trace data is typically derived as output from a network simulator like ns or from real network measurements, e.g., using tcpdump. Steven McCanne wrote the original version as a member of the Network Research Group at the Lawrence Berkeley

National Laboratory, and has occasionally improved the design, as he's needed it in his research. Marylou Orayani improved it further and used it for her Master's research over summer 1995 and into spring 1996. The nam development effort was an ongoing collaboration with the VINT project. Currently, it is being developed at ISI by the SAMAN and Consider projects.

The Trace File

The trace file is an ASCII code files and the trace is organized in 12 fields as shown below.

Table1: Fields of Trace File .

Event	Tim e	From Node	To node	Pkt type	Pkt size	Flag s	Fi d	Src addrs	Dst addrs	Seq num	Pkt id

The first field is the event type and given by one of four available symbols r, +, - and d which correspond respectively to receive, enqueued, dequequed and dropped. The second field is telling the time which the event occurs. The third and fourth fields are the input and output node of the link at which the events takes place. The fifth is the packet type such as continuous bit rate (cbr) or transmission control protocol (tcp). The sixth is the size of the packet and the next field is some kind of flags. The eighth field is the flow identity of IPv6, which can specify stream color of the NAM display and can be use for further analyze purposes. The ninth and tenth fields are the source and destination address in the form of “node.port”. The eleventh is the network layer protocol’s packet sequence number. NS keeps track of UDP packet sequence number for the analysis purposes. The twelfth, which is the last field, is the unique identity of the packet. Results of simulation are stored into trace file (*.tr). Trace Graph was used to analyze the trace file.

The Tracegraph

It is a data presentation system for Network Simulator NS2. The simulator doesn’t have any options implemented to analyse simulations results so it’s hard to use it. Trace graph [47] system provides many options for analysis, including 250 graphs and statistical reports. It is implemented in MATLAB 6.0 and can be compiled to run without MATLAB. Compiled versions for Linux and Windows systems are available for download at http://www.geocities.com/tracegraph/.

Trace graph supports the following NS2 trace file formats; wired, satellite, wireless (old and new trace), wired-cum-wireless. Trace file loading stage is divided into 4 stages; automatic trace file format recognition, trace file parsing to extract necessary simulation data which is saved to a temporary file, trace files can contain much more data than is needed by the system, so unnecessary information is omitted to speed up trace file loading, temporary file loading, constants calculations (packets types, packets sizes, flows IDs, trace levels, number of nodes, simulation time) – in order to speed up data processing. Wireless and wired-cum-wireless trace files are parsed and saved in Trace graph format.

The Low Rate WPAN Function Modules

The LR-WPAN [14] function modules were developed by Jianliang Zheng and Myung J. Lee (2006) at The City University, New York. The work was done specially for a newly defined standard IEEE 802.15.4. They had study and developed several features such as beacon enabled mode and non-beacon enabled mode, association, tree formation and network auto-configuration, orphaning and coordination relocation, CSMA-CA for both slotted and un-slotted and direct, indirect and GTS data transmissions.

Wireless Scenario Definition: It selects the routing protocol; defines the network topology; and schedules events such as initializations of PAN coordinator, coordinators and devices, and starting (stopping) applications. It defines radio-propagation model, antenna model, interface queue, traffic pattern, link error model, link and node failures, super-frame structure in beacon enabled mode, radio transmission range, and animation configuration.
Service Specific Convergence Sub-layer (SSCS): This is the interface between 802.15.4 MAC and upper layers. It provides a way to access all the MAC primitives, but it can also serve as a wrapper of those primitives for convenient operations. It is an implementation specific module and its function should be tailored to the requirements of specific applications.

802.15.4 PHY: It implements all 14 PHY primitives.

802.15.4 MAC: This is the main module. It implements all the 35 MAC sub-layer primitives.

Simulation of Routing Protocols
Simulation of different routing protocols (Flooding, Directed Diffusion and AODV) has been carried over to evaluate the performance. Various parameters that are considered for simulation are listed in table.

1.5 Performance Evaluation

This paper shows the results of the simulation. The analysis is being done on the basis of the results of *.nam file and the *.tr file. We also evaluate the performance of the protocol. In the ns2-allinone package NAM is a build-in program. NAM helps us to see the flow of message between the nodes. It also shows the packets are dropping or reaching to the destination properly. When the TCL file is written, NAM is invoked inside that file. With the help of 2D and 3D graphs we have tried to analyze the simulation with different simulation time. The scripts for the NAM is stored as *.nam and for tracegraph *.tr is used. The simulation has been mainly divided in three parts that are given below: Simulation of flooding protocol Simulation of Directed Diffusion protocol Simulation of AODV with WPAN The comparison between Flooding and Directed Diffusion is performed over the common factors like throughput of dropped packets, end-to-end delay and energy consumption in the network over different simulation time. Also for short-range communication, AODV with WPAN has been implemented over different topologies.

1.6 Simulation of Flooding Protocol

Simulation of flooding protocol is performed over 30 nodes having energy 7 joules. Nodes in the network are in random position. In this scenario there is a source node that will broadcast the data and all the neighbouring nodes will do the same after receiving it. Node 7 is the source node and node 5 is the sink node. Source node 7 is flooding the data to its neighbouring nodes. The flooding of packets is shown by red color. Because all the nodes are flooding the data, so there will be energy loss in the network continuously. When a particular node receives a fix amount of data it changes its color to show the energy loss. some nodes became yellow due to receiving more broadcast and so more energy loss.

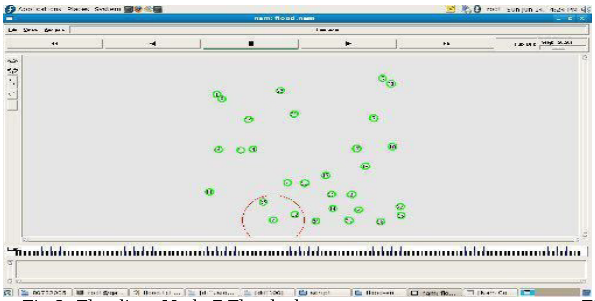

Fig 2: Flooding: Node 7 Floods data

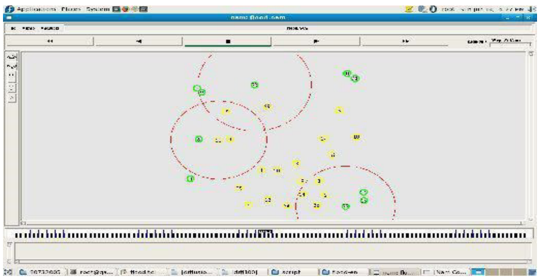

Fig 3: Flooding: The nodes, receive more broadcast became yellow

All the nodes are in the critical situation and network is going to collapse. The lifetime of the network with energy 7 joule is almost 85 seconds. If energy of the network is increased, it will work for more simulation time. After the simulation time of 85 seconds sensor network is not going to send or receive any kind of message because energy of all the nodes on the path between source and sink has been diminished.

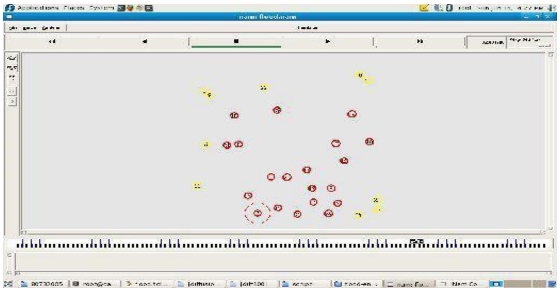
Fig 4:Flooding: Network in Collapsed State

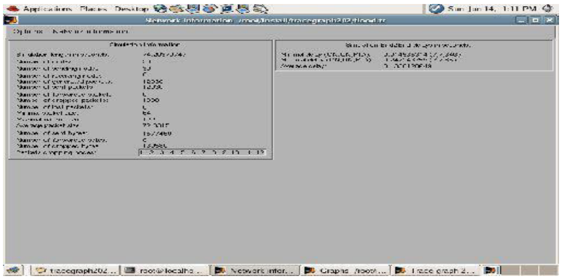
Fig 5: Flooding: Simulation Details

The trace graph snapshots have been taken with the simulation time of 75 seconds. The entire simulation scenario has been displayed along with the end-to-end delay. The throughput of sending and receiving protocols has been displayed

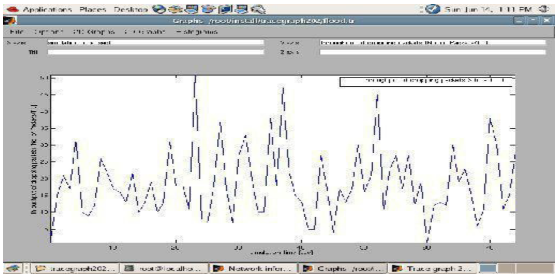
Fig 6:Flooding: Throughput of Sending Packets vs Simulation Time

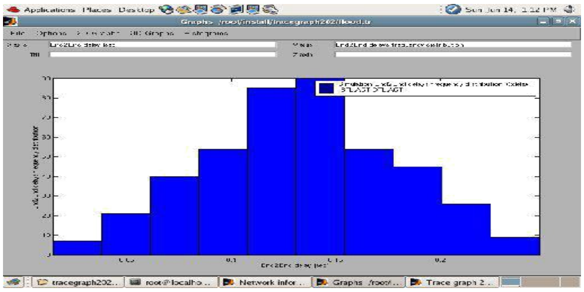
Fig 7:Flooding: End- to-end Delay Frequency Distribution

End to end delay is increasing continuously because all the nodes on the straight path have lost all the energy. So to reach to the destination a comparatively long path is being followed by the message which implies the more end to end delay. End-to-end delay with its frequency distribution is being shown. The minimum delay in this scenario is 0.014s and maximum delay is 0.247s. The average delay of this flooding protocol is 0.13s. The cumulative frequency distribution has been shown in figure 6.8, which implies that the cumulative delay is increasing continually to 0.24s.

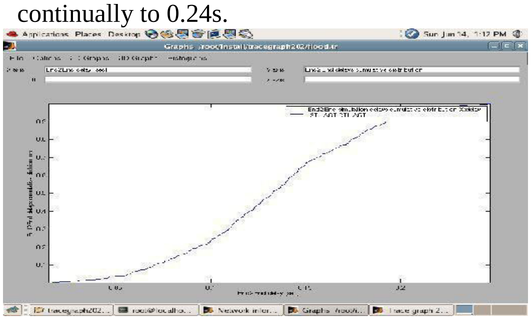
Fig 8:Flooding: End-to-end Delay Cumulative Distribution

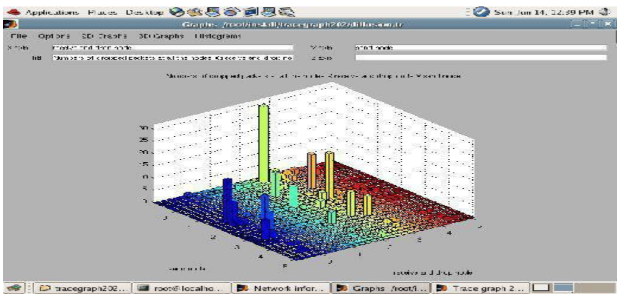
Fig 9:Directed Diffusion: Dropped Packets

Simulation of Directed Diffusion Protocol

The same topology has been implemented for directed diffusion with same source node and same sink node. The difference between the simulation of flooding and directed diffusion is that in directed diffusion, the communication starts from sink itself. When the sink sends the interest about what it needs, source node sends a gradient in reply and then data is being delivered to the sink.

In this simulation scenario, node 7 is the source node and node 5 is the sink node. Sink node 5 sends the interest Source node 7 is sending. In figure 9, sink node 5 is sending interest to all the neighbouring nodes. All the nodes in the network have a cache to store the different interests.

The trace file of the directed diffusion is diffusion.tr. Simulation information of the sensor network has been shown. The throughput of sending, receiving packets has been shown respectively. The number of dropped packets at all nodes has been shown

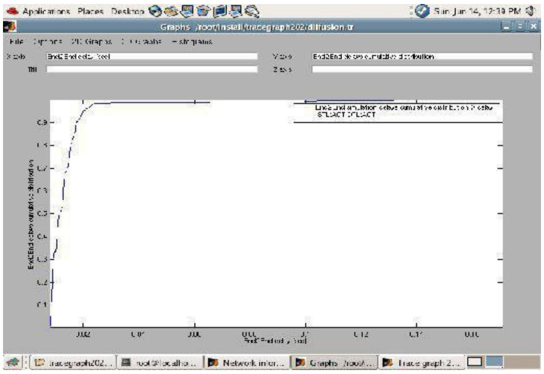

Fig 10:Directed Diffusion: End-to-end Delay Frequency distribution Comparison in Flooding and Directed diffusion

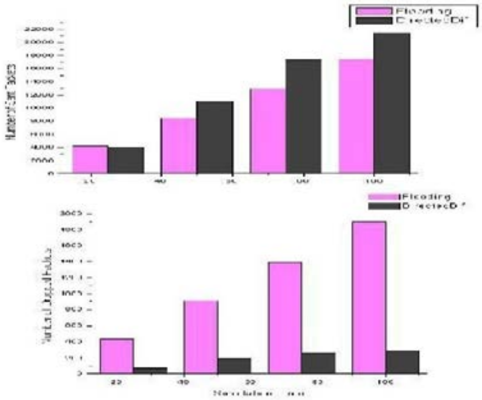

Figure11: Comparison in Flooding and Directed Diffusion

Table 2: Comparison inFlooding and Directed Diffusion Protocols

Protocol	**Initial Energy**	**Remaining**	**Network Lifetime**
	(joules)	**Energy (joules)**	**(seconds)**
Flooding	7	2.701	85
Directed Diffusion	7	2.904	90

Simulation of AODV Protocol

In the simulation of simple AODV, experiment is carried over 25 nodes. Through name file it can be easily analyzed that the packets are dropping or reaching to the destination properly or not.

AODV Random Topology

The animation capture in figure 14, shows that the source is broadcasting its data to all its neighboring nodes. The source (node 20) is broadcasting RREQ message to all its neighbors and Node 4, which is the destination node, is sending RREP (route reply) back to the source. RREP in red color has been shown , a packet in blue color is transmitting from the source (node 20) to the destination (node 4). As the energy of the nodes decreases, packet dropping starts. Node no. 1 has lost its energy completely and a packet dropping has been shown. As the packet dropping starts, again broadcast will happen and different route will be followed.

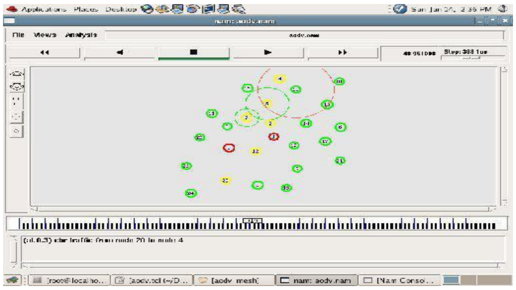

Fig 12: AODV (Random Topology): Network in Collapsed State

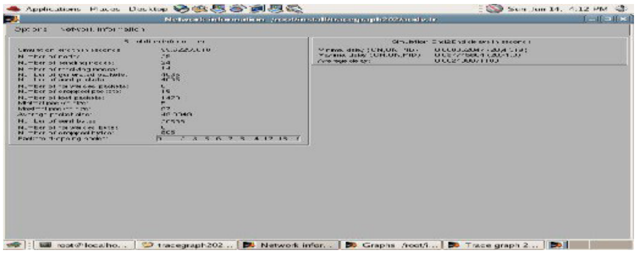

Fig 13: AODV (Random Topology): Simulation Details

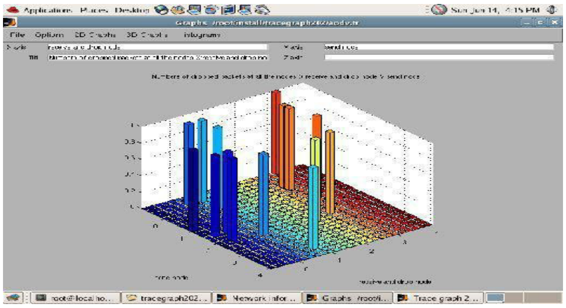

Fig 14: AODV (Random Topology): Dropped Packets

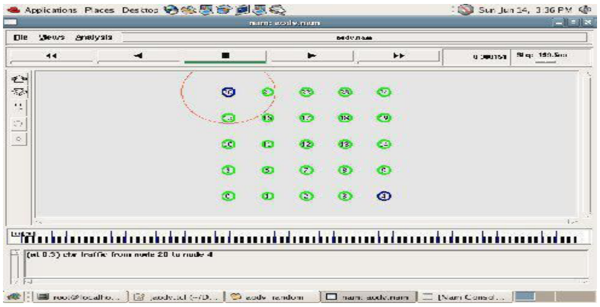

Fig 15:AODV (Mesh Topology): Source Node Broadcasts RREQ

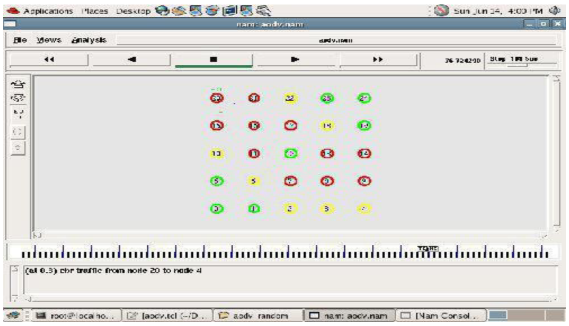

Fig 16: AODV (Mesh Topology): Network in Collapsed State

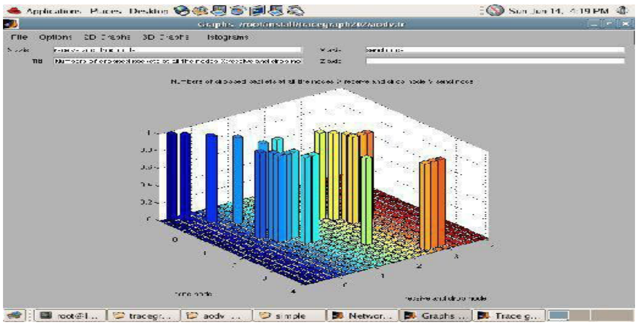

Fig 17:AODV (Mesh Topology): Dropped Packets

2. Conclusion and Future Work

Routing is a significant issue in Wireless Sensor Networks. The objectives listed in the problem statement have been carried out properly. In the presented work, we have discussed a comparison of two routing protocols for wireless sensor network with different simulation times. Also AODV over WSN is simulated with different topology changes. We sincerely hope that our work will contribute in providing further research directions in the area of routing.With the results of tracegraph, we can conclude that in the case of flooding, throughput of delivered packets is quite less than the throughput in the case of directed diffusion. Also end-to-end delay is also better in the case of directed diffusion. Since energy of the nodes is a constraint in wireless sensor network, so a fix amount of energy is given to the network in both the cases. As the simulation time increases, nodes in the network continuously lose its energy and after a fix simulation time network collapse. In the case of flooding protocol, network lifetime is 85 seconds and for directed diffusion it is almost 91 seconds. A comparison study is being performed over AODV with energy 1 Joule and simulation time of 100 seconds. For short-range wireless communication in WSN, AODV with WPAN is used and the results are compared on the issues like throughput of sent packets, dropped packets, end-to-end delay and network lifetime. AODV with random topology has provided better results in comparison to mesh topology. AODV with WPAN is a nice option. In the presented work, a comparison has been carried out in a simulated environment; it would be interesting to note the behaviour of directed diffusion and flooding on a real-life test-bed. Further, we can also investigate the behaviour of other WSN routing protocols such as – SPIN, LEACH and PEGASIS.

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