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Empirical Evaluation of DSR and AODV Routing Protocols in Wireless Sensor Networks

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Abstract

Sensor network routing protocols must ensure the stability of the network infrastructure under varying network dynamics. Recovery from changes or failures is necessary to guarantee the availability of collection or dissemination paths. Routing protocols may react to path requests or proactively maintain a connected graph. The nodes communicate wirelessly and often self-organize after being deployed in an ad-hoc fashion. Because of highly dynamic in nature, performance of routing protocols is an important issue. The reactive routing protocols such as AODV and DSR are evaluated in the WSN environment. This paper presents simulation based comparison and performance analysis on different parameters like End-to-End delay and Packet delivery ratio of these protocols.

Keywords: Wireless Sensor Network (WSN), DSR, AODV, Routing Protocols

1. INTRODUCTION

A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, vibration, pressure, humidity, motion or pollutants and to cooperatively pass their data through the network to a main location. The more modern networks are bi-directional, also enabling control of sensor activity. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; today such networks are used in many industrial and consumer applications, such as industrial process monitoring and control and machine health monitoring.

The WSN is built of "nodes" from a few to several hundreds or even thousands, where each node is connected to one (or sometimes several) sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a micro-controller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created.

The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth. The topology of the WSN can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding

Routing protocols:

Routing is the process of selecting paths in a network along which to send network traffic. Routing is performed for many kinds of networks, including the telephone

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network, electronic data networks and transportation networks. Routing is often contrasted with bridging in its assumption that network addresses are structured and that similar addresses imply proximity within the network. Because structured addresses allow a single routing table entry to represent the route to a group of devices, structured addressing outperforms unstructured addressing in large networks, and has become the dominant form of addressing on the Internet, though bridging is still widely used within localized environments.

A routing protocol is a protocol that specifies how routers communicate with each other, disseminating information that enables them to select routes between any two nodes on a computer network, the choice of the route being done by routing algorithms. Each router has a priori knowledge only of networks attached to it directly. A routing protocol shares this information first among immediate neighbors, and then throughout the network. This way, routers gain knowledge of the topology of the network. The term routing protocol may refer specifically to one operating at layer three of the OSI model, which similarly disseminates topology information between routers.

Ad hoc routing protocols

An ad-hoc routing protocol is a convention, or standard, that controls how nodes decide which way to route packets between computing devices in a mobile ad hoc network . In ad-hoc networks, nodes are not familiar with the topology of their networks. Instead, they have to discover it. The basic idea is that a new node may announce its presence and should listen for announcements broadcast by its neighbors. Each node learns about nodes nearby and how to reach them, and may announce that it, too, can reach them. The protocols are categorized according to the techniques followed to discover the routes and reach the destination. The protocols such as AODV and DSR considered for this study are of the type, “Reactive”. This type of protocols finds a route on demand by flooding the network with Route Request packets.

Ad hoc On-Demand Distance Vector (AODV)

Ad hoc On-Demand Distance Vector (AODV) Routing is a routing protocol for mobile ad hoc networks (MANETs) and other wireless ad-hoc networks. It is a reactive routing protocol, meaning that it establishes a route to a destination only on demand. In contrast, the most common routing protocols of the Internet are proactive, meaning they find routing paths independently of the usage of the paths. AODV is, as the name indicates, a distance-vector routing protocol. AODV avoids the counting-to-infinity problem of other distance-vector protocols by using sequence numbers on route updates. AODV is capable of both unicast and multicast routing.

Dynamic Source Routing (DSR)

DSR is a routing protocol for wireless mesh networks. It is similar to AODV in that it forms a route on-demand when a transmitting computer requests one. However, it uses source routing instead of relying on the routing table at each intermediate device. Determining source routes requires accumulating the address of each device between the source and destination during route discovery. The accumulated path information is cached by nodes processing the route discovery packets. The learned paths are used to route packets. To accomplish source routing, the routed packets contain the address of each device the packet will traverse. This may result in high overhead for long paths or large addresses, like IPv6. To avoid using source routing, DSR optionally defines a flow id option that allows packets to be

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forwarded on a hop-by-hop basis.

This protocol is truly based on source routing whereby all the routing information is maintained at mobile nodes. It has only two major phases, which are Route Discovery and Route Maintenance. Route Reply would only be generated if the message has reached the intended destination node. To return the Route Reply, the destination node must have a route to the source node. If the route is in the Destination Node's route cache, the route would be used. Otherwise, the node will reverse the route based on the route record in the Route Request message header. In the event of fatal transmission, the Route Maintenance Phase is initiated whereby the Route Error packets are generated at a node. The erroneous hop will be removed from the node's route cache; all routes containing the hop are truncated at that point. Again, the Route Discovery Phase is initiated to determine the most viable route. This paper evaluates the performance of the AODV and DSR routing protocols in the WSN.

2. RESEARCH BACKGROUND

The AODV routing protocol enables multihop routing between the participating mobile nodes wishing to establish and maintain an ad-hoc network. AODV is a reactive protocol based upon the distance vector algorithm. The algorithm uses different types of messages to discover and maintain links. Whenever a node wants to try and find a route to another node it broadcasts a Route Request (RREQ) to all its neighbors. The RREQ propagates through the network until it reaches the destination or the node with a fresh enough route to the destination. Then the route is made available by uncasing a RREP back to the source.

The algorithm uses hello messages (a special RREP) that are broadcasted periodically to the immediate neighbors. These hello messages are local advertisements for the continued presence of the node, and neighbors using routes through the broadcasting node will continue to mark the routes as valid. If hello messages stop coming from a particular node, the neighbor can assume that the node has moved away and mark that link to the node as broken and notify the affected set of nodes by sending a link failure notification (a special RREP) to that set of nodes.

DSR is a reactive routing protocol i.e. determines the proper route only when packet needs to be forwarded. For restricting the bandwidth, the process to find a path is only executed when a path is required by a node. In DSR the sender (source, initiator) determines the whole path from the source to the destination node (Source-Routing) and deposits the addresses of the intermediate nodes of the route in the packets. Compared to other reactive routing protocols like ABR or SSA, DSR is beacon-less which means that there are no hello-messages used between the nodes to notify their neighbors about their presence. DSR was developed for MANETs with a small diameter between 5 and 10 hops and the nodes should only move around at a moderate speed.

DSR is based on the Link-State-Algorithms which mean that each node is capable to save the best way to a destination. Also if a change appears in the network topology, then the whole network will get this information by flooding. The DSR protocol is composed of two main mechanisms that work together to allow discovery and maintenance of source routes in MANET.

The AODV and DSR are the reactive routing protocols. The routes are discovered only on demand. Both the protocols discover routes only in the presence of the data packets in the need for the route to the destination. Route discovery is based on a query and rely cycles and route information is stored in all

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intermediate nodes on the route. Since the overall characteristics and methodology of these two protocols in discovering and maintaining the routing information varies through minor differences, this study has a main focus of empirically evaluating the performance of these protocols. The packet delivery ratio and the end-to-end delay of the AODV and DSR protocols are evaluated in this article.

3. RELATED WORKS

Kemal and Mohamed (2005), this paper surveys recent routing protocols for sensor networks and presents a classification for the various approaches pursued. The three main categories explored in this paper are data-centric, hierarchical and location-based. Each routing protocol is described and discussed under the appropriate category. Moreover, protocols using contemporary methodologies such as network flow and quality of service modeling are also discussed.

Gang et.al (2004), this paper investigates the impact of radio irregularity on the communication performance in wireless sensor networks. Radio irregularity is a common phenomenon which arises from multiple factors, such as variance in RF sending power and different path losses depending on the direction of propagation. From this experiments, the authors discovered that the variance in received signal strength is largely random; however, it exhibits a continuous change with incremental changes in direction. With empirical data obtained from the MICA2 platform, we establish a radio model for simulation, called the Radio Irregularity Model (RIM). This model is the first to bridge the discrepancy between spherical radio models used by simulators and the physical reality of radio signals. The result shows that radio irregularity has a significant impact on routing protocols, but a relatively small impact on MAC protocols.

Ya et.al (2000), in this paper, the author presented two algorithms for routing in energy-constrained, ad hoc, wireless networks. Nodes running these algorithms can trade off energy dissipation and data delivery quality according to application requirements. This algorithms work above existing on-demand ad hoc routing protocols, such as AODV and DSR, without modification to the underlying routing protocols. The major contributions are: algorithms that turn off the radio to reduce energy consumption with the involvement of application-level information, and the additional use of node deployment density to adaptively adjust routing fidelity to extend network lifetime. Algorithm analysis and simulation studies show that these energy-conserving algorithms can consume as little as 50% of the energy of an unmodified ad hoc routing protocol.

Lee and Gerla (2000), in this article the author describes that nodes in mobile ad hoc networks communicate with one another via packet radios on wireless multi-hop links. Because of node mobility and power limitations, the network topology changes frequently. Routing protocols therefore play an important role in mobile multihop network communications. A trend in ad hoc network routing is the reactive on-demand philosophy where routes are established only when required. This study proposed a scheme to improve existing on-demand routing protocols by creating a mesh and providing multiple alternate routes. This algorithm establishes the mesh and multipaths without transmitting any extra control message. The authors apply this scheme to the Ad-hoc On-Demand Distance Vector (AODV) protocol and evaluate the performance improvements by simulation.

Ian and Luke (2002), in this paper AODVjr, a simplified version of the AODV protocol, are described. AODVjr is

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compared in simulation to a full featured AODV implementation. The results show that AODVjr performs as well as AODV and describes other positive effects of a smaller protocol specification.

Chakeres and Belding-Royer (2004), this paper describes the event triggers required for AODV operation, the design possibilities and the decisions for this ad hoc on-demand distance vector (AODV) routing protocol implementation, AODV-UCSB. This paper is meant to aid researchers in developing their own on-demand ad hoc routing protocols and assist users in determining the implementation design that best fits their needs.

Marina and Das (2001), studied the problem of keeping the caches up-to-date in dynamic ad hoc networks. The authors evaluated three techniques to improve cache correctness in DSR namely wider error notification, route expiry mechanism with adaptive timeout selection and the use of negative caches. Simulation results show that the combination of the proposed techniques not only result in substantial improvement of both application and cache performance but also reduce the overheads

David. B and David. A (1996), presented a protocol for routing in ad hoc networks that uses dynamic source routing. The protocol adapts quickly to routing changes when host movement is frequent, yet requires little or no overhead during periods in which hosts move less frequently. Based on results from a packet-level simulation of mobile hosts operating in an ad hoc network, the protocol performs well over a variety of environmental conditions such as host density and movement rates. For all but the highest rates of host movement simulated, the overhead of the protocol is quite low, falling to just 1% of total data packets transmitted for moderate movement rates in a network of 24 mobile hosts. In all cases, the difference in length between the routes used and the optimal route lengths is negligible, and in most cases, route lengths are on average within a factor of 1.01 of optimal.

Leung et.al (2001), presented a distributed multi-path dynamic source routing protocol (MP-DSR) for wireless ad-hoc networks to improve QoS support with respect to end-to-end reliability. This protocol forwards outgoing packets along multiple paths that are subject to a particular end-to-end reliability requirement. A simulation study is performed to demonstrate the effectiveness of our proposed protocol, particularly the fact that MP-DSR achieves a higher rate of successful packet delivery than existing best-effort ad-hoc routing protocols, such as the dynamic source routing (DSR).

Tuteja et.al (2010), in this article explains that Mobile Ad-Hoc networks are highly dynamic networks characterized by the absence of physical infrastructure. In this paper, the authors are going to compare Mobile Ad-Hoc network routing protocols DSDV, AODV and DSR using network simulator NS2.34. This study have compared the performance of three protocols together and individually too. The performance matrix includes PDR (Packet Delivery Ratio), Throughput, End to End Delay, Routing overhead. This article compares the performance of routing protocols when packet size changes, when time interval between packet sending changes, when mobility of nodes changes.

4. WIRELESS SENSOR NETWORKS

A wireless sensor network is a collection of nodes organized into a cooperative network. Each node consists of processing capability (one or more microcontrollers, CPUs or DSP chips), may contain multiple types of memory (program, data and flash memories), have a RF transceiver (usually with a single omni-directional antenna), have a power source (e.g., batteries and solar cells), and accommodate various sensors and actuators.

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The Wireless sensor nodes can be imagined as small computers, extremely basic in terms of their interfaces and their components. These nodes usually consist of a processing unit with limited computational power and limited memory, sensors or Micro-electro-mechanical systems (MEMS), a communication device which is usually radio transceivers or alternatively optical, and a power source usually in the form of a battery. Other possible inclusions are energy harvesting modules, secondary ASICs, and possibly secondary communication devices (e.g. RS-232 or USB).

The base stations are one or more components of the WSN with much more computational, energy and communication resources. These stations act as a gateway between sensor nodes and the end user as they typically forward data from the WSN on to a server. Other special components in routing based networks are routers, designed to compute, calculate and distribute the routing tables. Many techniques are used to connect to the outside world including mobile phone networks, satellite phones, radio modems, long-range Wi-Fi links etc. Many base stations are ARM-based running a form of Embedded Linux.

The following are the main characteristics of a WSN, Power consumption constrains for nodes using batteries or energy harvesting, ability to cope with node failures, mobility of nodes, dynamic network topology, communication failures, heterogeneity of nodes, scalability to large scale of deployment, ability to withstand harsh environmental conditions, ease of use, unattended operation and power consumption

The WSN are deployed in an ad-hoc fashion, routing typically begins with neighbor discovery. Nodes send rounds of messages (packets) and build local neighbor tables. These tables include the minimum information of each neighbor's ID and location. This means that nodes must know their geographic location prior to neighbor discovery. Other typical information in these tables includes nodes' remaining energy, delay via that node, and an estimate of link quality.

Once the tables exist, in most WSN routing algorithms messages are directed from a source location to a destination address based on geographic coordinates, not IDs. A typical routing algorithm that works like this is Geographic Forwarding. In GF, a node is aware of its location, and a message that it is "routing" contains the destination address. This node can then computes which neighbor node makes the most progress towards the destination by using the distance formula from geometry. It then forwards the message to this next hop. In variants of GF, a node could also take into account delays, reliability of the link and remaining energy.

Another important routing paradigm for WSN is directed diffusion. This solution integrates routing, queries and data aggregation. Here a query is disseminated indicating an interest in data from remote nodes. A node with the appropriate requested data responds with an attribute-value pair. This attribute-value pair is drawn towards the request or based on gradients, which are set up and updated during query dissemination and response. Along the path from the source to the destination, data can be aggregated to reduce communication costs. Data may also travel over multiple paths increasing the robustness of routing.

Sensors establish and maintain routes either pro-actively or reactively. Pro-active protocols periodically monitor peer connectivity to ensure the ready availability of any path amongst active nodes. Sensors advertise their routing state to the entire network to maintain a common (partially) complete topology of the network. On the other hand, reactive protocols establish paths only upon request, e.g. in response to

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a query, or an event; meanwhile, sensors remain idle in terms of routing behavior. Sensors forward each routing request to peers until it arrives at a sink; the latter will respond over the reverse communication path.

Reactive routing protocols have been the protocols of choice in WSN, due to frequent node mobility. Due to their simplicity, and inherent support for data on demand, they have been the predominant design choice in WSN.

5. RESULTS & DISCUSSION

This section describes some of our experiences in evaluating DSR and AODV protocol using simulation. Simulation environment consists of a set of wireless and mobile networking extensions that have been created on the publicly available ns-2 network simulator from the University of California at Berkeley and VINT project. These extensions provide a detailed model of the physical and link layer behavior of a wireless network and allow arbitrary movement of nodes within the network. At the physical layer, realistic modeling of factors such as free space and ground reflection propagation, transmission power, antenna gain, receiver sensitivity, propagation delay, carrier sense, and capture effect are provided. At the link layer, models such as Distributed Coordination Function (DCF), Media Access Control (MAC) protocol of the IEEE 802.11 wireless LAN protocol standard, along with the standard Internet Address Resolution Protocol (ARP) are included. These wireless and mobile networking extensions are available from the Carnegie Mellon University Monarch Project web pages and have been widely used by other researchers; a version of them have also now been adopted as a part of the standard VINT release of ns-2[55].

A number of different simulation studies with this environment, analyzing the behavior and performance of DSR and comparing it to AODV routing protocol for ad-hoc networks have been done. Some basic results are summarized here which indicate the efficient performance of DSR. In the results presented here, all simulations were run in ad-hoc networks of 10, 20 and 50 mobile nodes moving according to the random way point mobility model within a flat rectangular (1500m $\times$ 300m) area; all simulations were run for 15 minutes (900 seconds) of simulated time. Data traffic was generated using Constant Bit Rate (CBR) UDP traffic sources, with either 10, 20, or 50 mobile nodes acting as traffic sources generating 4 packets/second each. All movement and application-layer communication was generated in advance and captured in a scenario file, allowing us to rerun DSR or other ad-hoc network routing protocols on the identical workloads.

In the random waypoint mobility model, each mobile node begins at a random location and moves independently during the simulation. Each node remains stationary for a specified period called as pause time and then moves in a straight line to some new randomly chosen location at a randomly chosen speed up to some maximum speed. Once reaching that new location, the node again remains stationary during the pause time, and then chooses a new random location to proceed to at some new randomly chosen speed, and the node continues to repeat this behavior throughout the simulation run. This model can produce large amounts of relative node movement and network topology change, and thus provides a good movement model with which to stress DSR or other ad- hoc network routing protocols.

Performance Metrics

The following two metrics describes the most basic overall performance of DSR and AODV protocols studied in this paper. Packet Delivery Ratio: The ratio between

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number of packets originated by the application layer sources and the number of packets received by the sinks at the final destination. End-to-End Delay: This is defined as the delay between the time at which the data packet was originated at the source and the time it reaches the destination. Data packets that get lost en route are not considered. Delays due to route discovery, queuing and retransmissions are included in the delay metric. The metrics are measured against various mobility scenarios and with varying number of data connections.

The packet delivery ratio is important as it describes the loss rate that will be seen by the transport protocols, which in turn affects the maximum throughput that the network can support. This metric characterizes both the completeness and correctness of the routing protocol. The end-to-end delay metrics are measured to find the optimum time taken to deliver the content from source to destination. Protocols that send large numbers of routing packets can also increase the probability of packet collisions and may delay data packets in network interface transmission queues.

Packet Delivery Ratio Analysis

The following figure shows the fraction of originated application data packets were each protocol was able to deliver, as a function of both node mobility rate (pause time) and network load (number of sources). It is measured as follows:

$$PDR = \frac{no.\ of\ \ packets\ received}{no.\ of\ \ packets\ sent} \times 100$$

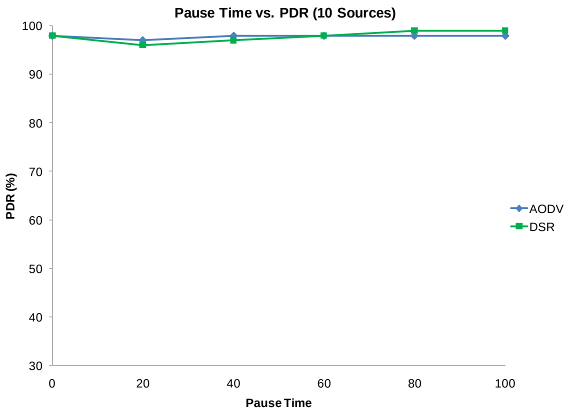

Figure 1: Packet Delivery Ratio for 10 Sources

It is observed from the figure 1 that packet delivery ratio of AODV and DSR seem identical. Both protocols are delivering their performance between 97% and 100% of packets in all cases. The last two instance state that DSR performance was better than AODV performance. Another experiment has been conducted for taking packet delivery ratio with 20 sources, which is depicted in figure 2. The increase in sources tends to reduce the packet delivery ratio. The delivery accuracy is between 91% and 95% and also evident that this experiment also has similar impact as previous experiment. With reference to performance, DSR perform better in last scenario.

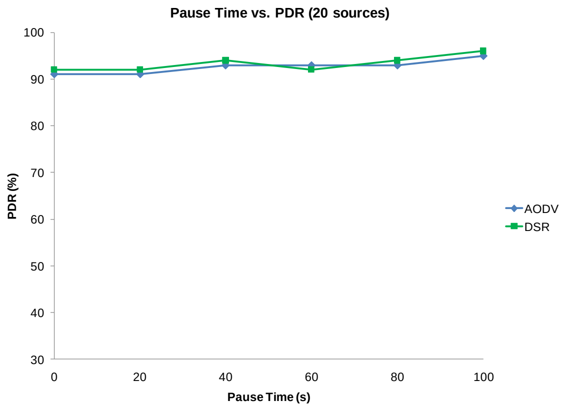

Figure 2: Packet Delivery Ratio for 20 Sources

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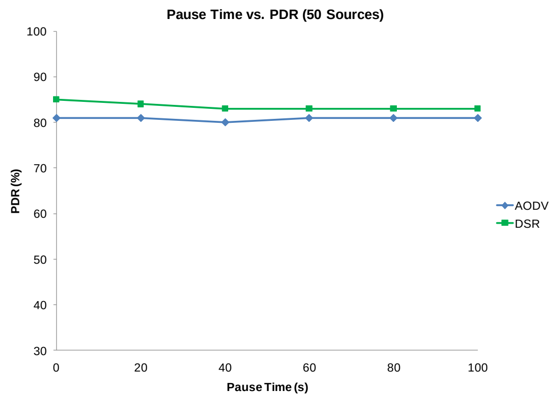

Figure 3: Packet Delivery Ratio for 50 Sources

The performance evaluation of two protocols with 50 sources depicted in figure 3 states that increase in number of sources reduces the packet delivery ratio, which is performed between 80% and 85%. It is also noticed in this experiment that in all instance the DSR performed better than AODV. There is a significant difference of performance found ($t = 8.0$, $P \leq 0.001$) between DSR and AODV, which infers that DSR performance is best with respect to packet delivery ratio.

Average End-to-End Delay Analysis

The delay is affected by high rate of CBR packets as well. The buffers become full much quicker, so the packets have to stay in the buffers a much longer period of time before they are sent.

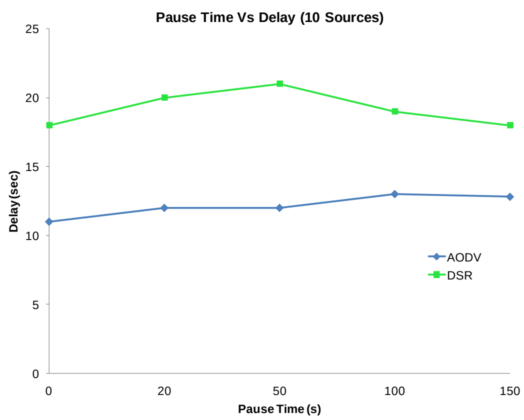

Figure 4: End-to-End Delay vs Pause Time for 10 sources

Figure 4, exhibits end-to-end delay versus pause time performance of DSR and AODV protocols. It can be observed from the figure that average packet delay occurs between 11 to 18 seconds and AODV performs better than DSR in all scenarios containing 10 nodes.

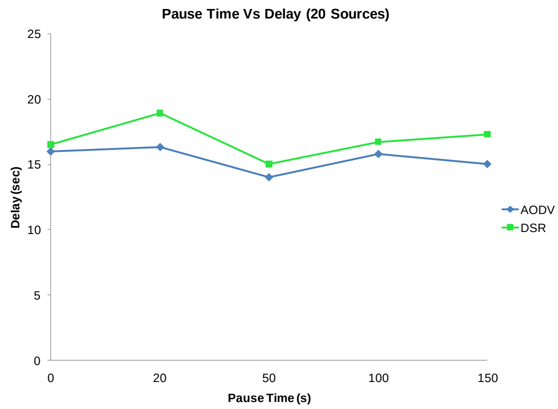

Figure 5: E2E Delay vs. Pause Time for 20 sources

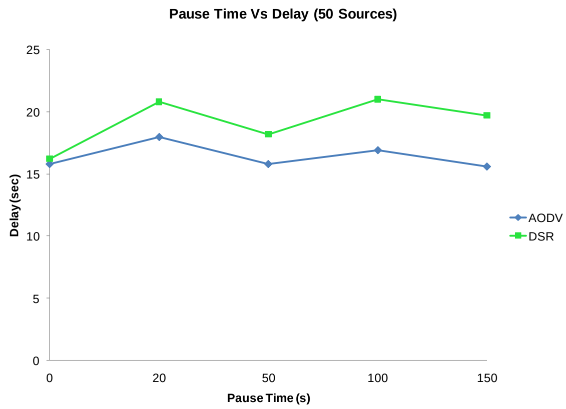

Figure 6: E2E Delay vs. Pause Time for 50 sources

The figure 5 and 6 exhibits the end-to-end delay measure with respect to 20 and 50 sources. In all delay measures DSR protocol consumes more time than AODV protocol, as it carries source routing till destination. Besides the actual delivery of data packets, the delay time is also affected by route discovery, which is the first step to begin a communication session. The source routing protocols have a longer delay because their route discovery takes more time as every intermediate node tries to extract information before forwarding the reply. The same thing happens when a data packet is forwarded hop by hop. Hence, while source routing makes route discovery more profitable, it slows down the transmission of packets.

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6. CONCLUSION

This study reveals comparative performance evaluation of DSR and AODV routing protocols in wireless sensor networks. The DSR provides excellent performance for routing in multi-hop wireless ad-hoc networks. As shown in our detailed simulation studies and in implementation of the protocol, DSR has very low routing overhead and is able to correctly deliver almost all originated data packets, continuously to all nodes in the network.

A key reason for this good performance is the fact that DSR operates entirely on demand, with no periodic activity of any kind required at any level within the network. For example, DSR does not use any periodic routing advertisement, link status sensing, or neighbor detection packets, and does not rely on these functions from any underlying protocols in the network. This entirely on-demand behavior and lack of periodic activity allows the number of routing overhead packets caused by DSR to scale all the way down to zero, when all nodes are approximately stationary with respect to each other and all routes needed for current communication have already been discovered. As nodes begin to move more or as communication patterns change, the routing packet overhead of DSR automatically scales to only that needed to track the routes currently in use. End-to-End delay performance shows that DSR routing protocol consumes more delay than AODV protocol.

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