

A Comparative Study of Routing Protocols in Wireless Sensor Networks

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Abstract

A wireless sensor network can be pictured as a collection of wireless sensing nodes that are spatially spread in a sensing field. Acting as a data collecting devices, sensors can measure, communicate with each other, and relay data to the base station. The end user can consequently utilize the conveyed data to monitor and take the required actions based on the monitored environment. In this article, we present a performance comparison of two well-known routing protocols, namely, Destination-Sequenced Distance Vector (DSDV) and Ad-hoc On Demand Distance Vector (AODV). Both DSDV and AODV are used in wireless sensor networks to aid sensor nodes communicate and transfer data from source to destination in an ad hoc multi-hop scenario. The network simulator NS3 is used for evaluation of both routing protocols. Four performance metrics are considered: Throughput, end-to-end delay, packet delivery ratio, and energy consumption. Simulation results showed that the AODV protocol achieved better performance than the DSDV protocol in terms of throughput, packet delivery ratio, and energy consumption.

Keywords: Wireless sensor networks, Routing, AODV, DSDV.

Introduction:

Wireless sensor networks consist of sensing (measuring) elements, known as nodes, which compute and communicate to help administrators react to events and phenomena in a desired environment. This environment

can be any of the physical world, information technology framework, or biological system. Sensor networks have served a plethora of applications such as national security, data collection, monitoring, surveillance, and medical telemetry (1). In general, the main components of a sensor network can be categorized into four entities. First entity is the sensing field which is the area wherein the sensor nodes are spread and placed such as a home, a forest, or a nuclear plant. The second entity is the sensor nodes which are autonomous devices consisting of sensing unit, processing unit, radio transceiver and power unit. The task of sensor nodes is to collect data and cooperate with other sensor nodes to convey this data to a central node called the sink. The third entity is the sink node which is typically a sensor node with enhanced capabilities of processing, storage and energy. The fourth and last entity is the task manager, also known as base station (BS), which serves as an interface between the end user and the network (1, 2).

Routing, in essence, plays a crucial role in wireless sensor networks. The term "Routing" in this context means enabling data exchange between source and destination over a designated network. This data exchange can be achieved in either single-hop or multi-hop scenarios (3). To accomplish conveying data between sensor nodes and base stations, two steps are required. Firstly, paths (routes) need to be established between the source and destination, especially in cases where the sender and receiver are not on the same link. Secondly, upon selecting which paths are suitable between the two entities, data traffic is forwarded by the help of intermediate nodes between source and destination. Routing algorithms are utilized for this matter to decide which path is 'Best' based on several parameters and metrics (3). These metrics depend mainly on the application requirements such as lowest end-to-end delay, highest throughput, least power consumption, best link quality, and/or least hop count. In multi-hop scenario, participation of intermediate nodes is a must in order to forward data traffic from source to destination. Consequently, determining which set of nodes is required to constitute the best path is one of the main responsibilities of routing algorithms (3, 4). However, designing a routing protocol for wireless sensor networks can be challenging due to some factors. These challenges include node deployment, energy consumption, fault tolerance, nature of nodes, node coverage, scalability, topology maintenance, and quality of service (QoS) requirements (3, 4).

In this paper, a comparison of ad hoc on demand distance vector (AODV) and destination-sequenced distance vector (DSDV) routing protocols is conducted in order to investigate and evaluate the performance of these two protocols. The network simulator NS3 is used for evaluation. Different scenarios are considered with several metrics and parameters to thoroughly examine the performance of these routing protocols.

Related Work

Many routing protocols have been presented in the literature considering different applications demands. Roberts *et al.* (5) proposed a reliable and energy-efficient routing protocol for improved high-performance for IoT applications. This protocol considers different criteria to enhance data management quality such as congestion, energy consumption, encrypted data transfer, and attacker node surveillance. Similarly, Al-Sadoon *et al.* (6) targeted the IoT domain by proposing a novel routing protocol dependent on dual-tier clustering concept and virtual network zones. The protocol aimed at enhancing the performance of mobile wireless sensor networks (MWSN). The Dual Tier Cluster-Based Routing (DTC-BR) was compared to other routing protocols and results showed enhancement in lifetime, low-energy consumption, and more efficient for large-scale WSNs. Classification and comparison of different categorized routing protocols have been presented by Zagrouba *et al.* (7). Simulation has been conducted and results showed that routing must be based on intelligent techniques to improve network lifetime and to ensure better sensing coverage area. Singh *et al.* (8) provided a comparison of AODV and DSDV routing protocols in mobile ad hoc networks (MANETs) focusing on node density and routing overhead. Based on their simulation results, DSDV performed better in terms of number of packets received and routing overhead, whereas AODV achieves better performance in terms of node density scenarios. In a different article, Singh *et al.* (9) investigated the performance and suitability of different versions of TCP traffic for wireless networks using both AODV and DSDV routing protocols. Amongst three variants of TCP, the Newreno type of TCP is preferred for better performance with both AODV and DSDV. Underwater sensor networks are also considered by researchers Wang *et al.* (10), where an efficient routing protocol were proposed based on reinforcement learning method. This routing algorithm utilizes the Q-learning to examine and

investigate the resource management in hierarchical networks. The results showed that the reinforcement routing protocol outperformed the conventional protocols in terms of reducing the delay and increasing the lifetime of the network. Considering MANETs, Singh *et al.* (11) studied the performance of three protocols, namely, DSDV, AODV, and DSR (Dynamic Source Routing). The DSR protocol showed better performance than DSDV and AODV in terms of packet delivery rate, throughput, and jitter. Performance analysis of two routing protocols, namely, AODV and DSDV has been conducted and reported in (12). Bandral *et al.* (12) stated that AODV outperformed DSDV in terms of QoS parameters such as packet loss ratio, end-to-end-delay, and throughput. Purnomo *et al.* (13) presented an investigation of utilizing routing protocols in health monitoring to assess the coverage area and mobility. The AODV, DSDV, and OLSR (optimized link state routing) protocols were studied and analyzed for the health monitoring purposes. Results showed that AODV outperformed the DSDV and OLSR in static conditions, whereas OLSR achieved better performance in the case of mobility. Alternatively, Goyal *et al.* (14) proposed an energy aware routing protocol over LEACH (Low Energy Adaptive Clustering Hierarchy) on wireless sensor networks. The authors emphasized on enhancing the network lifetime and energy consumption as compared to the legacy LEACH protocol. Gupta *et al.* (15) provided another approach for evaluating AODV by considering hardware chip. Once the hardware part was completed and tested, AODV routing protocol was also tested for wireless sensor network scenario in terms of throughput, packet delivery rate, and delay. Shukla *et al.* (16) assessed the performance of the AODV and DSDV routing protocols in MANETs under active black hole assault. The effectiveness of DSDV and AODV protocols was examined in the presence and absence of black hole assaults.

Materials and Methods:

In this study, two routing protocols are considered for comparison, namely, Destination-Sequenced Distance Vector (DSDV) and Ad-hoc On Demand Distance Vector (AODV). The DSDV routing protocol is a proactive, table-driven protocol based on the classical Bellman-Ford routing mechanism. However, some improvements were made to the Bellman-Ford algorithm in order to overcome loops in routing tables. On the other hand, the

AODV is a reactive and source-initiated routing protocol. The AODV can be called a pure on-demand route acquisition system; nodes that do not lie on active paths, neither maintain any routing information nor participate in any periodic routing table exchanges. Further, a node does not have to discover and maintain a route to another node until the two are needed to communicate, unless the former node is offering its services as an intermediate forwarding station to maintain connectivity between two other nodes.

The performance of the AODV and DSDV routing protocols is evaluated using the Network Simulator NS3 (17). The NS3 is simply a discrete event-driven simulation tool that has proven to be useful in studying the dynamic nature of communication networks. This simulator consists of two key languages: C++ and Object-Oriented Tool Command Language (OTcl). On the other hand, different performance metrics are considered including: Throughput, end-to-end delay, packet delivery ratio (PDR), and energy consumption. The number of sensor nodes is varied between 25 and 200. Simulation parameters used in our simulation are summarized in Table 1. Several scenarios have been constructed where each scenario is run for 500 seconds. Each scenario is run for 10 times and we have calculated the average values to obtain stable results.

Table 1. Simulation Parameters

Parameter	Value
Number of nodes	25 – 200
Simulation area	700x700
Simulation time	500 Seconds
Traffic type	CBR
Payload size	512 Bytes
MAC Protocol	IEEE 802.11
Reflection model	Two-ray ground
Mobility model	Random way point

Results and Discussion:

In our simulation, we have used different performance metrics to evaluate the performance of the AODV and DSDV routing protocols. We varied the number of sensor nodes and the traffic generated in each scenario.

Throughput of both DSDV and AODV routing protocols are plotted against the number of nodes as illustrated in Figure 1. The AODV achieves better performance in terms of throughput. This is can be interpreted since the AODV is a reactive protocol which means less overhead generated. Nonetheless, DSDV entails larger overhead for route management and maintenance, which consequently degrades the throughput. Our results agree with the results reported in (11-13, 16), where throughput of the AODV protocol outperforms that of the DSDV protocol.

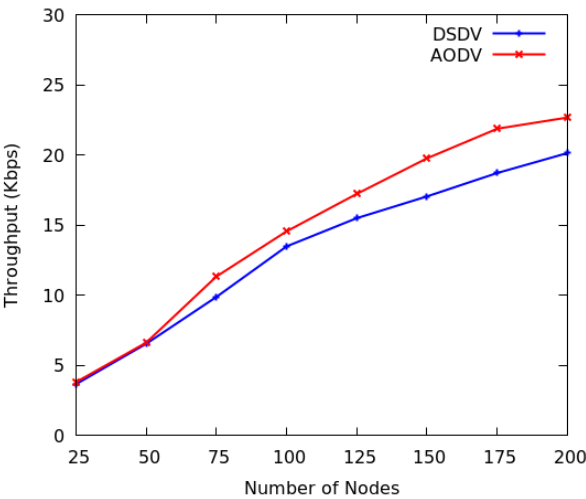


Figure 1. Throughput of DSDV vs. AODV

The results of end-to-end delay are depicted in Figure 2. The AODV protocol experiences larger delay than the DSDV protocol. To our best knowledge, this is a consequence of the nature of the AODV scheme as it takes some time to send the RREQ and receives RREP. However, the DSDV encounters lower delay as the routes to all destinations are known due to the proactive nature of the DSDV protocol. The obtained results of this study are in agreement with delay results presented in references (12, 13). However, the

end-to-end delay experienced by DSDV is reported to be lower than that of the AODV in reference (16).

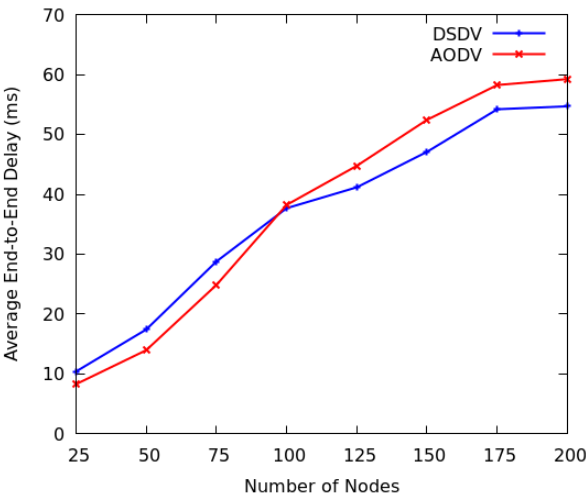


Figure 2. Delay of DSDV vs. AODV

Packet delivery ratio (PDR) is a performance metric that measures the percentage of packets that were able to reach their destinations out of all generated packets. The PDR of AODV and DSDV of our scenario is shown in Figure 3. As the figure illustrates, both protocols achieve high packet delivery ratio.

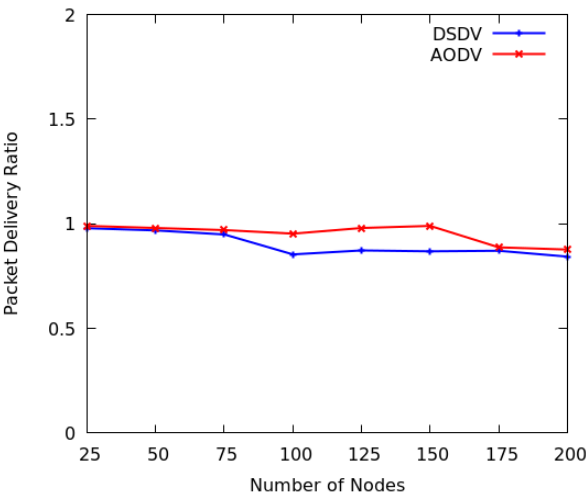


Figure 3. Packet Delivery Ratio (PDR) of DSDV vs. AODV

However, AODV shows a slightly better performance of PDR. This explains the higher throughput achieved by the AODV. We also observe that PDR of DSDV decreases when the number of nodes is equal or greater than 100. This is understood as the network becomes very dense with heavy traffic. That is, more packets will be dropped as the number of nodes increases. Agreeing with our simulation findings and according to the results reported in (12, 13, 16), the packet delivery ratio using the protocol AODV records higher number of packets delivered than the case when using the DSDV protocol. Nonetheless, the packet delivery ratio of the DSDV protocol in reference (11) is reported to be higher than AODV protocol.

Energy consumption gives a hint on which protocol is more suitable for scenarios where energy is the main concern. Figure 4 shows the simulation results regarding energy consumption for the DSDV and AODV protocols. It is clearly noticed from Figure 4 that AODV outperforms the DSDV protocol. These results indicate that DSDV consumes more energy due to the large overheads. The DSDV uses more routing messages in order to manage the routing table as well as the advertising table. Based on our literature review, there is no mention for energy consumption when evaluating the AODV and DSDV protocols. There are many protocols in the literature that consider the energy consumption as a crucial criterion, such as LEACH protocol (2).

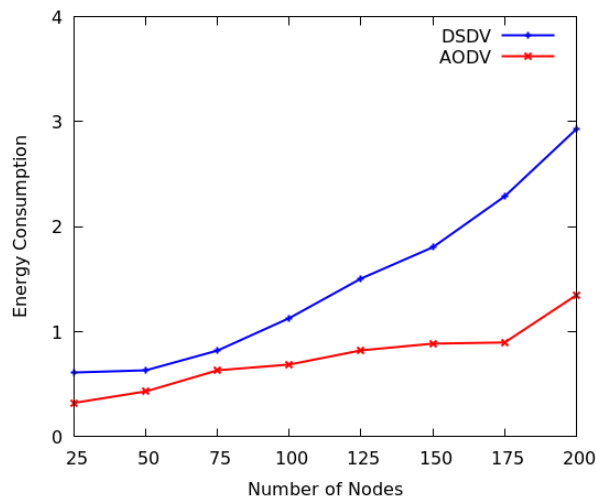


Figure 4. Energy consumption of DSDV vs. AODV

Conclusion:

Wireless sensor networks comprise many sensor nodes that perform significant tasks in different application domains such as tracking targets in military, environment monitoring, detecting catastrophic events, and health applications. Routing in wireless sensor networks plays a central role in delivering data from sources to destinations. Many routing protocols have been proposed and are being used in sensor networks. In this study, we have provided a description of sensor networks and routing protocols. To acquire a better understanding, we have conducted simulation of AODV and DSDV routing protocols. The network simulator NS3 was used to conduct our simulation scenarios. Simulation results showed that AODV outperformed the DSDV protocol in terms of throughput, packet delivery ratio, and energy consumption. However, the AODV experienced higher average end-to-end delay when the network becomes dense with heavy traffic.

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دراسة مقارنة لبروتوكولات التوجيه في شبكات الاستشعار اللاسلكية

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شبكة الاستشعار اللاسلكية يمكن تصورها على أنها مجموعة من عقد الاستشعار اللاسلكية التي تنتشر مكانياً في حقل الاستشعار. تعمل أجهزة الاستشعار كأجهزة لجمع البيانات، ويمكنها القياس والتواصل مع بعضها البعض ومن ثم إرسال البيانات إلى المحطة الأساسية. يمكن للمستخدم النهائي بالتالي استخدام البيانات المنقولة للمراقبة واتخاذ الإجراءات المطلوبة والقرارات بناءً على البيئة التي تتم مراقبتها. في هذه المقالة، نقدم مقارنة بين أداء بروتوكولي توجيه مشهورين، وهما ناقل المسافة المتسلسل للوجهة (DSDV) ومتجه المسافة حسب الطلب (AODV). يتم استخدام كل من DSDV و AODV في شبكات الاستشعار اللاسلكية لمساعدة عقد الاستشعار على الاتصال ونقل البيانات من المصدر إلى الوجهة في سيناريو متعدد القفزات. تم استخدام محاكي الشبكة NS3 لتقييم بروتوكولي التوجيه. تم أخذ أربعة مقاييس للأداء في الاعتبار: الإنتاجية، والتأخير، ونسبة تسليم حزم البيانات، واستهلاك الطاقة. أظهرت نتائج المحاكاة أن بروتوكول AODV قد حقق أداءً أفضل من بروتوكول DSDV من حيث الإنتاجية ونسبة تسليم حزم البيانات وكذلك من حيث استهلاك الطاقة.

الكلمات المفتاحية: شبكات الاستشعار اللاسلكية، بروتوكولات التوجيه، DSDV، AODV

