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Implementation of the AODV Routing in an Energy-constrained Mesh Network

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Abstract. Wireless sensor networks (WSNs) compose the fundamental platform for a number of Internet of Things (IoT) applications, especially those related to the environmental, health, and military surveillance. While being autonomous in power supply, the main challenge in node's processing and communication architecture design remains the energy efficiency. However, this goal should not limit the main functionality of the system which is often related to the network coverage and connectivity.

This paper shows the implementation of the Ad-hoc On-demand Distance Vector (AODV) routing algorithm in an XBee based platform. As shown, the network can achieve low power consumption per node primarily due to the energy efficiency of the wireless transceivers and the due to the capability of the firmware to enable different operation modes. On the other hand, while inheriting the advantages of flooding-based route discovery protocols, the implemented AODV algorithm further minimizes the data and processing overhead, which implies the additional lifetime prolongation of the energy-constrained mesh network.

Keywords: AODV, routing, wireless sensor networks, XBee

1. Introduction

Wireless Sensor Networks and Mobile Ad Hoc Networks (MANETs) have attracted great academic and engineering attention due to the technology trend convergence towards the concept of IoT. A Wireless Sensor Network indicates a particular type of network which is characterized by a distributed architecture created from a set of autonomous electronic device which are able to sense, scan and pick up information from their surroundings and able to communicate with each other [1]. Recent technological advances have enabled wireless communications and digital electronics to be able to develop small low-power devices, which are multifunctional and able to communicate with each other via wireless technologies [2]. A typical WSN represents a wireless network composed of small power-autonomous nodes that sense the physical parameters from the environment, locally process them, and sends the sensed data wirelessly towards the destination. In addition to the constraints implied from the limited ICT resources, WSN's application requirements include self-organizing capabilities as well as robustness to the electromechanical influences and to the topology changes. With the same fundamental constraints, MANETs additionally presume the higher level of mobility, which again implies slightly different approaches in network design. With the given application requirements, the MANETs networking protocol design goes far beyond the well-established networking protocols that are present in today's Internet. Since nodes are usually battery supplied (or alternatively by some other means of limited sources), the main goal in the design of the protocols is minimizing the power consumption in a relatively highly dynamic networking topology, while optimizing the other ordinary application requirements such as network coverage, link capacity, latency, network robustness, reliability, security, etc. This approach is used in most of the protocol design, in each of the networking layer.

Routing in MANETs is a challenge that, due to the mentioned limitations, is still not standardized and is highly application-specific. There are many routing protocols proposed in literature, but only few of them are implemented. The Ad-Hoc On- Demand (AODV) routing protocol is one of the most popular reactive protocol for ad hoc networks.

This paper presents an implementation and energy-focused analyze of the AODV protocol in an XBee enabled platform.

The paper is structured as follows. Section 2 presents the main WSNs' challenges and routing philosophies. Section 3 presents the experimental setup while the appropriate results are briefly discussed in Section 4. Finally, Section 5 concludes the paper.

2. Mesh networks and routing

Mesh networks offer scalable and flexible architecture, since the number of deployed sensor nodes may vary from couple to hundred, thousands or millions. Accordingly, the design of the communication protocols must be focused on enabling new concepts such as ad-hoc clustering, multi-hop routing, energy efficiency, etc. Furthermore, the network must preserve its stability even when new nodes are introduced into the network, which means that additional communication messages will be exchanged in order for the new nodes to be integrated into the network [3].

2.1 Main challenges in WSNs

The requirements of each WSN or MANET based application may vary significantly. In most cases, several elements should be considered in order to make the best design decisions.

Fault tolerance is one of the main attributes of the network, especially important in applications where the network is deployed in the inaccessible regions such as forests, battlefields, etc. It presents the network capability to function without interruption even in case of failure of one or more sensor nodes. In this situation, adaptive network protocols should be implemented. For example, the AODV protocol is able to establish new links in case of node failures or in case a better route is available [4].

Network deployment can also be categorized in two ways: nodes can be densely or sparsely deployed [4][2]. Also, sensor network can be deployed randomly or in deterministic manner. The critical WSN implementation challenges raise when the network is dense and when the nodes are deployed randomly. In these cases the protocols should be ready to deal with the issues such as coverage, connectivity, collisions, interference, traffic overhead (in the process of creating and maintaining the routes), energy efficiency, etc. The AODV protocol, by its functionality nature, enables for the addressing of most of last issues.

Power consumption remains one of the main challenges in WSNs and MANETs. The main issue is implied from the fact that a wireless sensor node is a microelectronic device equipped with a limited amount of power source [5]. These devices are expected to be of miniature physical dimensions, to meet the ICT requirements and, at the same time, to live for as long as possible while supplied from the battery or from the alternative energy sources. Hence power conservation and power management are the important issues of the architecture design. Due to this reason, researches are mostly focused on the design of power aware protocols and algorithm for sensors networks [5]. The Digimesh firmware that is used in the experimental setup in the proceeding section, and which relies on AODV philosophy, enables for the execution of power aware multi-hop routing.

Besides the given challenges and constraints, WSNs pose many additional limitations (that are usually considered as secondary) such as the implementation cost, latency, complexity, etc.

2.2 Routing and AODV

Routing techniques are required in order to enable the data path between sensor nodes and the sink node/s [6][7]. Based on various parameters including their mode of functioning and type of target applications, the protocols can be classified as proactive, reactive and hybrid [6].

2.2.1 Routing protocols and mesh networks

In the environments where a proactive protocol is used, the communication between nodes and/or gateway is performed through a predefined route. Hence, known as table-driven routing protocol, a proactive protocol serves as a requirement establishment for nodes which need to be able to equip their routing table with the latest data in order to be able to establish and perform any required connection [8]. So, whenever a node needs to send a specific packet, there is no need to search for the route. Instead, the route is already there. This implies for the high delay reduction. However, there are many disadvantages of this routing philosophy. First, the protocol efficiency is poor if the topology changes rapidly [9]. Second, the routes are actively and periodically maintained, and the entries in the routing tables exist even though the routes might not be active for a while. Furthermore, these routing protocols constantly maintain routes (which even may never be used) and consume bandwidth to keep routes up-to-date for bringing the only advantages – provision of little or no delay for route determination [6]. Some representative types of proactive routing protocols are [7]: Optimized Link State Routing Protocol (OLSR), Destination Sequenced Distance Vector (DSDV), Wireless Routing Protocol (WSR).

On the other hand, in order to discover a route, the reactive routing protocols flood the network. This decreases the bandwidth utilization but scales well in frequently changing network topologies [9]. However, the route maintaining process does not incur much overhead, since the route maintenance is limited to only those destinations which are target of receiving data. This construction leads to a conclusion that reactive routing protocols are best suited for networks with higher nodes' mobility. Some representative reactive or On-demand routing protocols [6] are: DSR (Dynamic Source Routing), TORA (Temporally Ordered Routing Algorithm), ABR (Associativity Based Routing), AODV (Ad-Hoc On-Demand Distance Vector).

Typically, the networks which operate under hybrid routing protocols are separated into specific regions and/or zones [10]. Here, the routing protocols are created as a result of mixing the usage of proactive and reactive routing protocols [8][6]. Each node maintains routing information for a specific zone. That is, communication between nodes is kept updated in a proactive way. On the other hand, zones are interconnected with each other by using reactive routing protocols which is highly bandwidth efficient, especially in case of rarely changing inter-zone communication. Hybrid approaches provide a compromise on scalability issue in relation to the frequency of end to-end connection, the total number of nodes, and the frequency of topology change.

2.2.2 The AODV

The AODV protocol reduces control traffic by originating path requests only on demand. To monitor active neighbors, AODV uses stateless hello messages. Upon failure, it generates an error message to notify upstream sensors that use the broken path to avoid it [11]. When a broken link is discovered and an alarm is triggered to notify that a prior valid path now it is not usable some processes are triggered in order to retain the path to the destination. Even though the path monitoring and route table management are as important as the path construction, this section will cover only route creation process. An event or alarm will trigger a route request only if a valid path to the sink doesn't exist[12]. Paths expire either implicitly, e.g. routing state timeouts, or implicitly, e.g. error packets sent. Sensors buffer their data packets until they receive a reply [13]. There can be more than one outstanding request at a time, identified by a sequence number. Route requests are broadcast [14], constrained by a TTL hop count limit which is used to reduce flooding redundancy [15]. Maximum path length is its default value [14]. All intermediate relays compete with each other to become part of the best path; they increment an additive metric (e.g. hop count) and rebroadcast the request; meanwhile they cache the sender as the next hop to the originator. The AODV protocol uses implicit acknowledgements to determine bidirectionality between any pair of sensors [11]. If a sensor marks, or blacklists, a link as unsteady, it ignores it in the path discovery process [1][12].

Once the request is receipt, a path is established by sinks in reverse: thus the reply is propagated by them using as the next relay to the originator the previous sensor [30][7]. A sink is capable of receiving more than one request per source, even though the first request is able to traverse the path fastest [6]. Moreover, the gateway or sink is able to reinforce multiple paths toward the originator. Depending on the strategy which is being used, these paths can be discarded, used, or stored. Reply messages are unicast, rather than multicast [12][11]. Sensors are able to generate free replies, in case they already

maintain an active path toward the destination [6]. This does not guarantee optimality, but improves responsiveness [6]. Nevertheless, it is important to notify sinks for path interests in order to monitor abnormal traffic patterns [6][9].

The AODV protocol offers a good balance between minimal overhead, good network reaction on dynamic route changes and acceptable latency. The mentioned reasons make it appropriate for the majority of MANET-based applications.

3. Experimental setup

The experimental scenario includes two sensor nodes and a sink node, as shown in fig. 1. Wireless communications are achieved by using XBee standard/modules while the mesh topology construction and the AODV implementation are provided by Waspmote Digimesh firmware [17].

Fig. 1: Network topology

Digimesh incorporates different modes of operations such as low power sleep modes with synchronized wake up, low power mode with variable sleep time, and low power mode with variable wake up time. This provides for the high power efficiency. It is also self-healing, i.e., the nodes can be added and removed without consequences in the sense of network connectivity. Finally, AODV is designed for ad-hoc communication manner and enables for the reliable data delivery by using acknowledging approach.

The aims of the experiments were to implement AODV/Digimesh protocol in performing multi-hop routing for energy conversation and communication coverage improvements. The case study is limited on temperature sensing.

So, the experiment has three phases:
   a) Temperature measurement in one node.
   b) The AODV execution, i.e., the executing of the AODV routing from end to end and sending the temperature measurements periodically.
   c) Measuring the energy efficiency.

4. The results

The energy consumption was measured per node. Measurements were performed in both cases - when nodes are sending data in static point-to-point manner, and when the data dissemination is made in multi-hop manner with AODV implemented.

For measuring the power consumption, the ampermeter is connected in series to measure the current. In both scenarios, the current is measured using same conditions, including nodes' distance, packet size etc. The current is measured in both active and sleep mode and the results are showed in table 1.

Table 1: Current drain with and without AODV implemented.

	Active Mode	Sleep Mode
One Hop routing	49 mA	0.7 mA
Multi-hop routing using AODV routing protocol	54 mA	0.9 mA

As can be noted, while being very efficient in dealing with the communication issues in dynamic mesh environments, the AODV protocol is also very energy efficient, which is one of the most important issues in WSNs and MANETs.

Conclusions

The paper presents an implementation of AODV routing protocol in temperature measurement. The analysis was focused on power efficiency of the AODV in multi-hop mesh networks. In order to derive the "energy weight" of the AODV, we have compared the power consumption of AODV enabled network with the one that does not use the AODV, using predefined same testing conditions and scenarios. From the derived measurement, it can be easily concluded that, besides its advantages in bandwidth utilization, relatively low latency, and a good response on topology changes, AODV protocol is also a "light" one in the sense of energy consumption. Hence, it is found to be suitable for use even in those applications where the power conservation is one of the primary limitations.

References

1   ChiaChiarara Buratti, Andrea Conti, Davide Dardari, Roberto Verdone, " An overvi overview on Wireless Sensor Networks Technology (ISSN 1424-8220;CODEN:SENSC9)," 2009
2   R. Flickenger, "Wireless Networking in the Developing World," 2006.
3   Dunfan Ye, Daoli Gong, Wei Wang, "Application of Wireless Sensor Networks in Environmental Monitoring," IEEE, 2nd Internation Conference on Power Electronics and Intelligent Transportation System, 2009.
4   Bruno R., Conti M., Gregori E., "Mesh Networks: Comodity multihop Adhoc Networks," IEEE, Communication Magazine , vol. 43, 2005.
5   Chulsung Park, Kanishka Lahiri, "Battery discharge characteristics of Wireless Sensor Nodes. An experimental analysis," Proceedings of the IEEE Conference on Sensor and Ad-hoc communications and Networks (SECON), 2005.
6   Alexandros Koliousis, Joseph Sventek, "Proactive vs reactive routing for wireless sensor networks".
7   Abdul Hadi Abd Rahman, Zuriati Ahmad Zukarnain, "Performance Comparison of AODV, DSDV and I-DSDV routing protocols in MObile Ad Hoc Networks," European Journal of Scientific Research ISSN 1450-216x, , vol. 31, pp. 556-576, 2009.
8   Hmalik M., Awais Q, Jamil M., Dhyani A., "Performance analysis of proactive and reactive protocols in mobile Ad-hoc networking," Islamabad 22-24, April, 2014.
9   Anjali Bhatt, Prashant Bhati, "Performance Analysis of reactive and proactive routing protocols for Vehicular Ad-hoc Networks," International Journal of Electrical and Electronics Research, vol. 2, no. 4, 2014.
10   Jamal N., Al-Karaki, Ahmed E. Kamal, "Routing Techniques in Wireless Sensor Networks".
11   Charles E. Perkins, Elizabeth M. Royer, "Ad Hoc on Demand Distance Vector Routing".

12 Ian D. Chakeres, Elizabeth M. Belding-Royer, "AODV Routing Protocol Implementation Design".

13 Elizabeth M. Royer, Charles E. Perkins, "An implementation study of the AODV routing protocol".

14 Iftikhar Ahmad, Uzma Ashraf, Sadia Anum, Hira Tahir, "Enhanced AODV route Discovery and Route Establishment for QOS provision for real time transmission in MANET," Interantional Journal of COmputer Networks & Communications , vol. 6, 2014.

15 Venetis Kanakaris, David Ndzi, Kyriakos Ovalladis, "Improving AODV Performance using dynamic density driven route request forwarding".

16 Guoyou He, "Destination-Sequenced Distance Vector (DSDV) Protocol".

17 Libelium, "Waspmote Digimesh Networking guide".