Efficient On-Demand Routing Protocols to Optimize Network Coverage in Wireless Sensor Networks

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Abstract

In recent years, wireless sensor networks (WSN) have found their way into a wide variety of applications and systems with vastly varying requirements and characteristics. Wireless networks are self-configurable, multihop networks formed by nodes having continuous mobility. This is an area in which close collaboration between users, application domain experts, hardware designers, and software developers is needed to implement efficient systems. The foremost challenge of WSN is in finding routes between source and destination with minimum power consumption, and this requirement has led to many routing protocols. In this paper, two novel routing protocols, namely, Zone Routing Protocol (ZRP) and Ad hoc On-demand Distance Vector for Clustering (C-AODV) routing protocol, that can provide optimum number of nodes with maximum throughput for a specific network area, has been proposed. Simulation results show that the optimum number of nodes remains the same for both the protocols and it varies identically, as the network area increases or decreases, due to limited radio range, mobility, contention etc. It has been observed that as the node mobility increases the throughput decreases for a fixed network configuration over an area.

Keywords: Wireless sensor network, Node optimization, zone routing protocol, C-AODV, Power efficiency, Data throughput.

1. Introduction

Wireless sensor network was originally defined as a large-scale (covering large geographical area) wireless, ad hoc, multihop, unpartitioned network of homogeneous, tiny (hardl noticeable), mostly immobile (after deployment) sensor nodes that would be randomly deployed in the area of interest. But, recent advances and application areas targeted by wireless sensor networks have necessitated to alter this definition of a wireless sensor network, such that, the networks may consist of heterogeneous and mobile sensor nodes. The advancement in mobile portable computing devices such as laptops, personal digital assistants and the advancements in wireless communication have made mobile computing possible and inevitable. One research area that has attracted the attention of scientific community recently is the mobile ad hoc network (MANET). A MANET is formed by a group of portable devices (nodes) having almost same functionality. It can be quickly deployed without an infrastructure or centralized administration. Nodes may be deployed at random (e.g. dropping them from an aircraft) or installed at deliberately chosen sports. However, deployment may also be a continuous process, with more nodes being deployed at any time during the use of the network, for example, to replace failed nodes or improve coverage at certain interesting locations. Each node acts as a store and forward station for routing packets. Nodes are required to deliver packets to the correct destinations. Two nodes wishing to communicate can do so directly if they are within the radio range of each other or route their packets through other nodes.

The functionality difference of MANET from traditional wired internet introduces unique challenges such as node mobility, unpredictable link properties, limited battery life etc. Mobility has a large impact on the expected degree of network dynamics, and hence influences the design of networking protocols and distributed algorithms. As the nodes are highly dynamic, maintaining routes become a greater challenge. Further, nodes may join and leave the network at any time. The actual speed of movement may also have an impact, for example, on the amount of time during which nodes stay within communication range of each other. Thus the routing algorithm must maintain and reconstruct the routing paths with minimal overhead and delay. There are few works which compared the performance of AODV and ZRP [4] [5]. But the routing protocol models of those works did not include any optimization. Though metrics such as control overhead, average latency, load, and data delivery have been considered for performance analysis, no optimization has been reported. These aspects are included in this study.

This paper is organized as follows: Section 2 outlines

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the functionality of the two widely applied reactive protocols C-AODV and ZRP. Section 3 describes the simulation model and scenario taken for simulation. Section 4 presents the analysis of the results and section 5 gives the conclusion.

2. Routing Protocols

Routing protocols for MANET may be broadly classified as proactive and reactive protocols [3]. The protocol is composed of two main mechanisms of "*Route Discovery*" and "*Route Maintenance*". The source node initiates route discovery when it does not have a route to the destination in its route cache. It does route discovery by flooding the network with Route Request packets. Each node receiving the (RREQ) packet rebroadcasts it, until it is the destination node or it has a route to the destination in its cache. Such a node replies to the RREQ with a route reply (RREP) that is routed RREQ builds up a path traversed across the network. RREP traverses by reversing the path of RREQ in case of bi-directional routes or it initiates a source discovery if it does not have a path to source in its *route cache* [2] [3]. In proactive routing schemes, the status of the entire network is maintained at all nodes, which limits its scalability [4]. In the case of reactive on demand routing schemes routes are established only when needed [4].

2.1 Zone Routing Protocol (ZRP)

In the Zone Routing framework, a proactive routing protocol provides a detailed and updated view of each node's surrounding local topology (routing zone) at the local level. The knowledge of local topology is used to support services such as proactive route maintenance, unidirectional link discovery and guided message distribution. One particular message distribution service, called bordercasting [5], directs queries throughout the network across overlapping routing zones. bordercasting is used in place of traditional broadcasting to improve the efficiency of a global reactive routing protocol. The benefits provided by routing zones, compared with the overhead of proactively tracking routing zone topology, determine the optimal framework configuration. As network conditions change, the framework can be dynamically reconfigured through adjustment of each node's routing zone. In Zone routing, the Intra zone Routing Protocol (IARP) proactively maintains routes to destinations within a local neighborhood, which we refer to as a routing zone. More precisely, a node's routing zone is defined as a collection of nodes whose minimum distance in hops from the node in question is no greater than a parameter referred to as the zone radius. An important consequence is that the routing zones of neighboring nodes overlap. The performance of the Zone Routing Protocol is determined by the routing zone radius. In general, dense networks consisting of a few fast moving nodes favor smaller routing zones. On the other hand, a sparse network of many slowly moving nodes operates more efficiently with a larger zone radius. The simplest approach to configuring the routing zone radius is to make the assignment once, prior to deploying the network. This can be performed by the network administration, if one exists, or by the manufacturer, as a default value. This may provide acceptable performance, especially in situations where network characteristics do not vary greatly over space and time. Alternatively, the ZRP can adapt to changes in network behavior, through dynamic configuration of the zone radius [6].

In Zone Routing with independently sized routing zones capability, each of the nodes in the network can adaptively configure its own optimal zone radius in a distributed fashion. The performance of Zone Routing is further improved by the ability to provide fine-tuned adaptation to local and temporal variations in network characteristics .

2.2 C-AODV

C-AODV is another on-demand routing protocol, which has characteristics very similar to that of ZRP. C-AODV also discovers routes on an as needed basis via a similar route discovery process. However C-AODV differs from ZRP in its route maintenance mechanism, it uses routing tables, one entry per destination C-AODV relies on routing table entries to propagate an RREP back to the source and, subsequently, to route date packets to the destination. C-AODV uses sequence number maintained at each destination to determine freshness of routing information and to prevent routing loops. All routing packets carry these sequence numbers [4] [5].

C-AODV maintains timer-based states in each node, regarding utilization of individual routing table entries. A routing table entry is expired if not used recently. RERR packets in C-AODV are intended to inform all sources using a link when a failure occurs. Route error propagation in C-AODV can be visualized conceptually as a tree whose root is the node at the point of failure and all sources using the failed link as the leaves.

C-AODV uses expanded ring search to control the RREQ floods in the route discovery process. Expanded ring search is used initially to discover routes to unknown destination. In expanded ring search increasing larger neighborhoods are searched to find the destination. The Time – To-Live (TTL) field in the IP header of the RREQ packets controls the search. If a route to a previously known destination is needed, the prior hop-wise distance is used to optimize the search. This enables computing the TTL value dynamically [1].

3. Implementation Results

3.1. The Simulation Model

A simulation model based on GloMosim – 2.03[6] is used for performance study. The implementation of ZRP and C-AODV closely matched their specifications. The routing protocol model "detects" all data packets transmitted or forwarded and responds by invoking routing activities as appropriate. The RREQ packets are considered as broadcast packets in the MAC. RREP and data packets are all unicast packets with a specified neighbour as the MAC destination. RERR packets are considered multicast in both C-AODV and ZRP.

Both protocols maintain a send buffer of 64 packets. It contains all data packets waiting for a route, such as packets for which route discovery has started, but no reply has arrived yet. To prevent buffering of packets indefinitely, packets are dropped if they wait in the send buffer for more than 30s. All packets sent by the routing layer are queued at the interface queue until the MAC layer can transmit them. The interface queue has a maximum size of 50 packets and it maintained as a priority queue with tow priorities each served in FIFO order. Routing packets get higher priority than data packets.

3.2 The Traffic And Mobility Models

Traffic sourced are assumed to be of constant bit rate (CBR). The source-destination pairs are spread randomly over the network. Only 512-byte data packets are used. The number of source destination pairs and the terrain dimension of each pair are varied to find the optimum node in a particular area.

The mobility model uses the random waypoint model in a square field. Here we have considered the mobility between 0-1 0 m/s and 0-20m/s. We have considered the MAC protocol as 802.11 and network protocol as IP.

3.3 Optimisation Parameter:

The increasing use of wireless devices and widening application area of MANETs necessitate the MANETs to be QoS aware. Designing the MANET to be QoS aware is a very complex process as it includes many issues. In this paper, the successful packet delivery is considered as the QoS parameter and considering this the number of nodes for a given network area is optimized. For comparison purpose, both ZRP and C-AODV routing protocols have been considered separately to find the optimum number of nodes which will yield maximum rate of successful delivery of packets.

3.4. Study Scenario

The scenario used for the simulation has been given in table 1.

TABLE 1: SIMULATION PARAMETERS

Simulation Time	15m
Node placement	Random
Mobility	Random Waypoint
Propagation Limit	-111.0 dBm
Propagation Path loss	Two-Ray
Temperature	290^0k
Network protocol	IP
Bandwidth	2MHz
Radio RX Type	SNR Bounded
Radio RX SNR Threshold	10.0 dB
Radio TX Power	15.0 dBm
Radio RX sensitivity	-91.0 dBm
Radio RX Threshold	-81.0 dBm

The simulation time represents the maximum simulation time. In random node placement the nodes are placed randomly within the physical terrain. In random waypoint mobility model, the node randomly selects a destination from the physical terrain. It moves in the direction of the destination in a speed uniformly chosen between MOBILITY-WP –MIN-SPEED and MOBILITY-WP-MAX-SPEED (meter/sec). After it reaches its destination, the node stays there for MOBILITY-WP-PAUSE time period. The bandwidth represents the bandwidth at which the node sends messages. Signals with powers below PROPAGATION-LIMIT (in dBm) are not delivered. This value must be smaller than RADIO-RX-SENSITIVITY + RADIO-ANTENA-GAIN of any node in the model. The two ray path loss model used free space path loss (2.0, 0.0) for near sight and plane earth path loss (4.0, 0.0) for far sight. The antenna height is hard-coded. Temperature of the environment is considered in Kelvin. Radio Rx type considered is packet reception model. In SNR bounded model, if the Signal to Noise Ratio (SNR) is more than RADIO-RX-SNR-THRESHOLD (in dB), it receives the signal without error. Otherwise the packet is dropped. The RADIO-RX-POWER is the transmission power (in dBm). The RADIO-RX-THRESHOLD is the minimum power for received packet (in dBm).

4. Results And Analysis:

Fig. 1 shows the node optimization for different terrain dimensions. For a 100mx 100m network area if the total number of nodes present in the area is less than 30 and greater than 4, it has been observed that the successful packet transfer 'S' is between 97.5% and 99.5%. For number-of-nodes (N) equal to 30, the successful packet transfer 'S' is exactly 100%, whereas for N>30 the value of 'S' decreases as N increases. Thus the optimum value of N for a terrain dimension of 100m x 100m is 30. for terrain dimensions of 200m x 200m, 250m x 250m and 500m x 500m the optimum values of N obtained from simulations are 35, 40 and 70 respectively. The loss of packets increases as nodes varies about an optimal value and this is shown in Figure 1. this is due to congestion in the channel and interference caused to the transmitted power. The loss of packets for N less than four is due to the non-availability of nodes within the limited radio range and link failure due to the increased diverging mobility of the transmitting nodes.

By comparing the results in figure 1, it is observed that the optimum value of N obtained for terrain dimension in ZRP closely matches with that of C-AODV. A study of the throughput characteristics of both the protocols ins shown in figure 2. Both the protocols exhibit identical behavior. The C-AODV has a slightly higher throughput. The figure 3 shows the power consumption of ZRP and C-AODV in which C-AODV gives better results. These advantages are gained with no compromise in control overheads or pause time which is shown in figure 4 and 5.

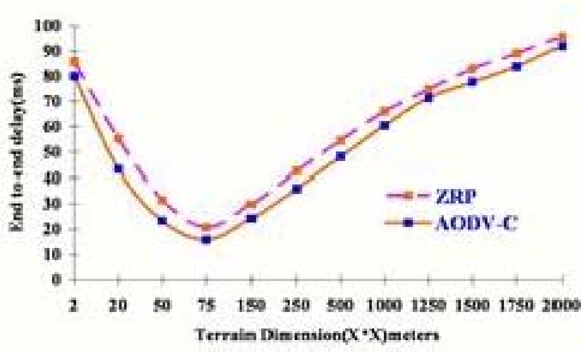

Figure 1 End to End delay for various dimensions with 40 nodes

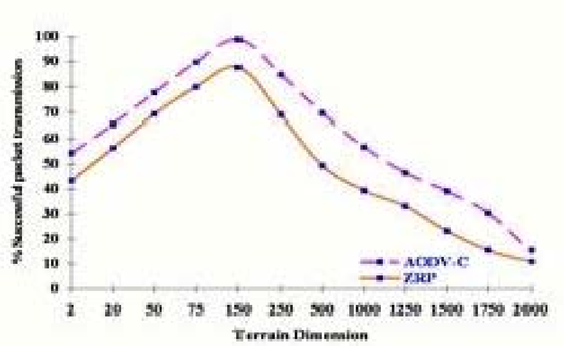

Figure 2 Data throughput for various dimension with 40 nodes

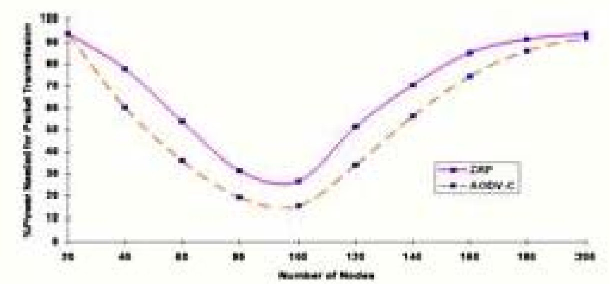

Figure 3 Comparison of power used by ZRP and AODV-C for

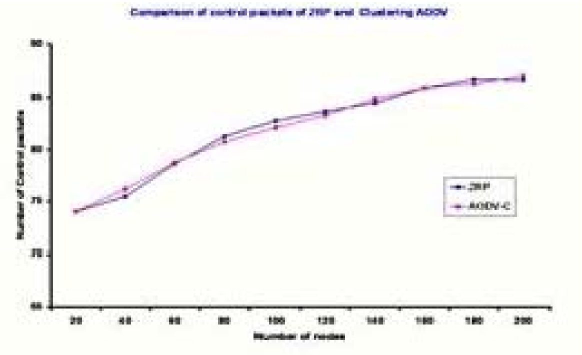

Figure 4 Comparison of control packets

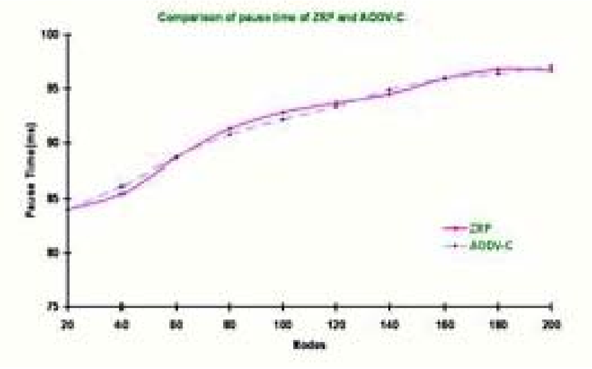

Figure 5 Comparison of pause time

5. Conclusion

In this work, the ratio of the data packets delivered to the destination to those generated by the CBR sources at the destination has been evaluated. The maximum packet received by the destination gives the optimum number of nodes in a particular terrain dimension. This metric is most important for best effort traffic. The first set of experiments uses differing number of sources with a moderate packet rate and varying terrain range. For the expeirement 10,16,20,26,30,36,40 traffic sources for varying terrain dimension is studied. A slower rate with 40 sources is used to avoid high network congestion. ZRP is found to outperform C-AODV in terms of throughput in smaller number of nodes and mobility. But C-AODV outperforms ZRP in case of increased loadn and mobility. ZRP generates less routing load than C-AODV. The inter-layer interaction between routing and MAC layers affects the performance significantly. The details of the Independent Zone Routing (IZR) framework are proposed to be included as a future direction of study.

References

[1] D.B. Johnson and D.A. Maltz, “zone Routing Protocol in Ad Hoc mobile wireless Networks,” Journal of Mobile Computing, pp153-181, 1996.

[2] Charles E.Perkins, Elizabeth M. Royer, Samir R.Das, “Ad hoc On-Demand Distance Vector (AODV) Routing”, draft-ietf-manet-AODV-06.txt, Mobile Ad hoc Networking Group, INTERNET DRAFT, June 1999.

[3] E.M. Royer and C. Toh. “A Review of current routing protocol for Ad hoc mobile wireless networks. “IEEE personal Communication, pp, 46-55 April 1999.

[4] Charles E. Perkins, Elizabeth M. Royer, Samir R. Das and Mahesh K. Marina, “performance Comparison of two On-Demand routing protocol for ad hoc networks,” IEEE Personal Communication, pp 16-28, Feb 2001.

[5] David B. Johnson, David A. Maltz, Yih – Chun Hu, “Zone Routing Protocol (ZRP) for mobile Ad hoc networks” draft-ietf-manet-ZRP-09. txt, IETF MANET Working Group. INTERNET –DRAFT, 15 April 2003.

[6] Jorge Nuevo, INRS- University du Quebec, “A Comprehensible GloMoSim Tutorial”, September 4, 2003.

[7] S. Roundy, D. Steingart, L. Frechette, P. Wright and J. Rabeay, “Power sources for ireless sensor networks,” Lect notes comput. Sci. 2920, 1-17,2004.

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