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HIERARCHICAL ROUTING BASED ON NEIGHBOUR COVERAGE IN WIRELESS SENSOR NETWORKS

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Abstract:

The overhead of a route discovery cannot be neglected. In a route discovery, broadcasting is a fundamental and effective data dissemination mechanism, where a node blindly rebroadcasts the first received route request packets unless it has a route to the destination, and thus it causes the broadcast storm problem. In this paper propose a Hierarchical routing protocol for neighbour coverage-based probabilistic rebroadcast for reducing routing overhead in WSN. Also define a Route Strength factor to provide the node density adaptation. By combining the additional coverage ratio and Route Strength factor, we set a reasonable rebroadcast probability. Our approach combines the advantages of the neighbour coverage knowledge and the probabilistic mechanism, which can significantly decrease the number of retransmissions so as to reduce the routing overhead, and can also improve the routing performance.

Key Words: Wireless Sensor Network, Neighbour Coverage, Route Strength Factor, Probabilistic Rebroadcast & Routing Overhead

1. Introduction:

Wireless sensor Network consists of a collection of Sink nodes which is a key ingredient of the various monitoring applications. These nodes can be performing data collection arbitrary topology networks with a fixed infrastructure. One of the fundamental challenges of WSN is the design of dynamic routing protocols with good performance and less overhead. Many routing protocols, such as Ad Sensor Protocols for Information via Negotiation and Minimum Cost Forwarding Algorithm (MCFA) (k.Seada, Apr 2004), have been proposed for WSNs. The above two protocols are Hierarchical routing protocols, and they could improve the scalability of WSN by limiting the routing overhead when a new route is requested [3]. However, due to node's, frequent link breakages may lead to frequent path failures and route discoveries, which could increase the overhead of routing protocols and reduce the packet delivery ratio and increasing the end-to-end delay (P. Casari, M. Nati, C. Petrioli, M. Zorzi, June 2007). Thus, reducing the routing overhead in route discovery is an essential problem. The conventional Hierarchical routing protocols use flooding to discover a route. Therefore, it is indispensable to optimize this broadcasting mechanism. Some methods have been proposed to optimize the broadcast problem in WSN in the past few years. Williams and Camp (S.Basagni,M.Nati,C.Petrioli, November/December 2008) (P. Casari, M. Nati, C. Petrioli, M. Zorzi, June 2007) categorized broadcasting protocols into four classes: "simple flooding, probability-based methods, area based methods, and neighbour knowledge methods." For the above four classes of broadcasting protocols, they showed that an increase in the number of nodes in a static network will degrade the performance of the probability-based and area-based methods (P. Casari, M. Nati, C. Petrioli, M. Zorzi, June 2007). (S. Basagni, I. Chlamac, V. R. Syrowardtiuk, B. A. Woodward, October 1998) indicated that the performance of neighbour knowledge methods is better than that of area-based ones, and the performance of area-based methods is better than that of probability-based ones. The main contributions of this paper are as follows: 1. we propose a novel scheme to calculate there broadcast delay. The rebroadcast delay is to determine the forwarding order. The node which has more common neighbours with the previous node has the lower delay. 2. We also propose a novel scheme to calculate there broadcast probability. The rebroadcast probability is composed of two parts: a. additional coverage ratio, which is the ratio of the number of nodes that should be covered by a single broadcast to the total number of neighbours; and b. connectivity factor, which reflects the relationship of network connectivity and the number of neighbours of a given node. The rest of this paper is organized as follows: Section 2 introduces the related previous work. Section 3 proposes a Neighbour Coverage-based Probabilistic Rebroadcast protocol for reducing routing overhead in route discovery. Section 4 presents simulation parameters and scenarios which are used to investigate the performance of the proposed protocol. Section 5 concludes this article.

2. Related Work:

According to its first and simplest formulation, geographic routing concerns forwarding a packet in the direction of its intended destination by providing maximum per-hop advancement (H. Takagi, L. Kleinrock, March 1984), (S. Basagni, I. Chlamac, V. R. Syrowardtiuk, B. A. Woodward, October 1998). In dense networks, this greedy approach is quite successful, since nodes are likely to find a path toward the sink traversing a limited number of intermediate relays. Conversely, in sparse networks, packets may get stuck at dead ends, which are located along the edge of a connectivity hole, resulting in poor performance. A number of ideas have, therefore, been proposed to address the problem of routing around dead ends. A first set of approaches stems from the work of Kranakiset al.. WSN topologies are first "planarized" (J. Gao, L. J. Guibas, J. Hershberger, L. Zhang, A. Zhu, Jan 2005). Geographic routing over planarized WSNs is then obtained by employing greedy routing as long as possible, resorting to planar routing only when required, for example, to get around connectivity holes. Heuristic rules are then defined for returning to greedy forwarding as soon as next-hop relays can be found greedily. Examples of this approach include (L. Barrie, P. Fraigniaud, L. Narayanan, J. Opatmy, 2001), (K. Moaveninejad, W. Song, X. Li, september 2005), (L. Blazevic, J-Y. Le Boudec, S. Giordano, March 2005) (Q. Fang, J. Gao, L. J. Guibas, April 2006) (Q. Huang, S. Bhattacharya, C. Lu, G. C. Roman,

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November 2005). Solutions based on planarization have several drawbacks. Planar routing may then require the exploration of large spanners before being able to switch back to the more efficient greedy forwarding, thus imposing higher latencies (Y. J. Kim, R. Govindan, Sep 2005). This is because spanner formation protocols assume that the network topology is modelled by a UDG, and the correctness of the approach cannot be guaranteed when this is not the case, as in most realistic situations. To make planarization work on real networks, a form of periodic signalling must be implemented to check that no links cross, as performed by the Cross-Link Detection Protocol (CLDP) (Y. J. Kim, R. Govindan, B. Karp, S. Shenker, May 2005). However, this is a transmission intense solution for WSNs, which eventually affects the network performance. For a comprehensive overview of planar graph routing, the reader is referred to the survey by Frey et al. [14]. A different class of solutions for handling dead ends is based on embedding the network topology into coordinate spaces that decrease the probability of connectivity holes. This category includes algorithms using virtual coordinates (L. Barrie, P. Fraigniaud, L. Narayanan, J. Opatmy, 2001) (K. Moaveninejad, W. Song, X. Li, September 2005), (L. Blazevic, J-Y. Le Boudec, S. Giordano, March 2005) (Q. Huang, S. Bhattacharya, C. Lu, G. C. Roman, November 2005) (Q. Fang, J. Gao, L. J. Guibas, April 2006), and those that perform some sort of topology warping . In the former case, the coordinates of each node are the vector of the hop distance between the node and each of a set of beacons. RS is a recent contention-based protocol presented by Ru¨ hrup and Stojmenovic to route packets around connectivity holes without requiring planarization. The protocol is designed to complement any greedy forwarding algorithm (including ALBA) by determining a next hop relay through a timer-based contention. The relay is chosen so that a traversal path is found that ensures progress after a greedy failure. RS is based on two delay functions, namely, sweep circle and twisting triangle (TT), providing different lengths for traversing paths, and is shown to achieve guaranteed delivery in UDGs. As such, however, it is not generally applicable, and it can be detrimentally affected by localization errors.

3. Hierarchical Routing Based Neighbour Coverage Protocol:

In this section, we calculate the rebroadcast delay and rebroadcast probability of the proposed protocol. We use the upstream coverage ratio of an RREQ packet received from the previous node to calculate the rebroadcast delay, and use the additional coverage ratio of the RREQ packet and the connectivity factor to calculate the rebroadcast probability in our protocol, which requires that each node needs its 1-hop neighborhood information.

4. Uncovered Neighbours Set and Rebroadcast Delay:

When node n_i receives an RREQ packet from its previous node s, it can use the neighbour list in the RREQ packet to estimate how many its neighbours have not been covered by the RREQ packet from s. Node n_i could further adjust If this random number is less than the threshold T (n), the sensor node is a cluster-head.

$$T(n) = \begin{cases} \dfrac{P}{1 - P[r \bmod (1/P)]} & \text{if } n \in G, \\ 0 & \text{otherwise,} \end{cases} \tag{1}$$

In order to sufficiently exploit the neighbour knowledge and avoid channel collisions, each node should set a rebroadcast delay.

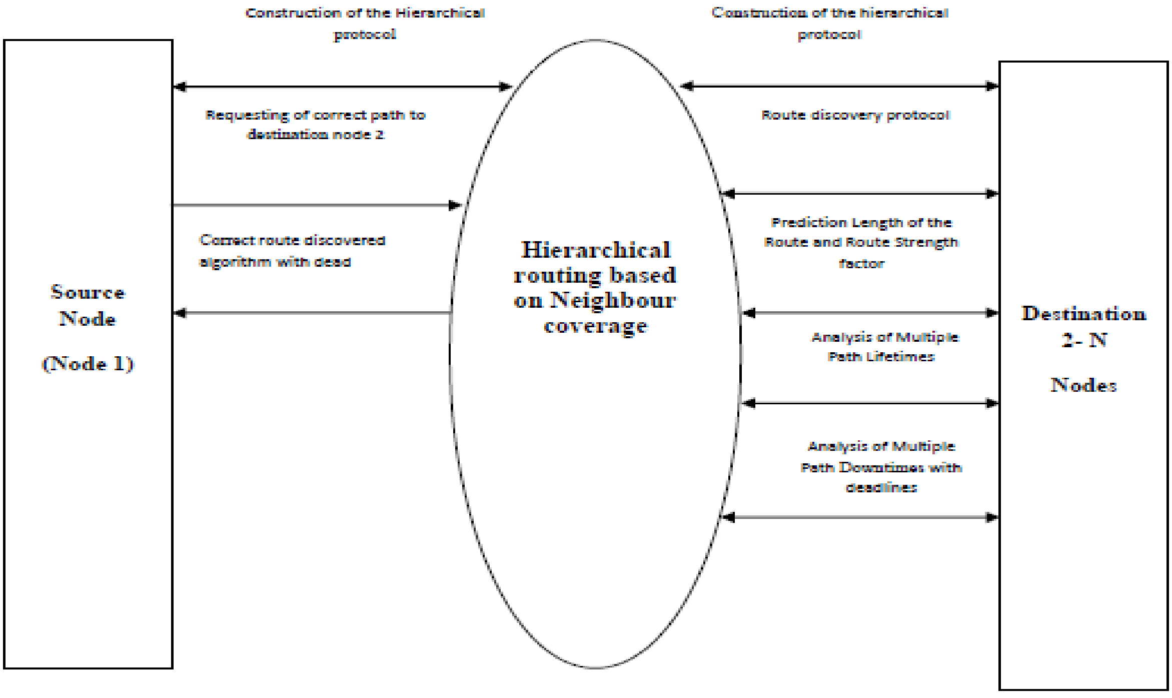

Figure 2: Architecture Diagram of Hierarchical routing based Neighbour Coverage

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The choice of a proper delay is the key to success for the proposed protocol because the scheme used to determine the delay time affects the dissemination of neighbour coverage knowledge. When a neighbour receives an RREQ packet, it could calculate the rebroadcast delay according to the neighbour list in the RREQ packet and its own neighbour list. We describe Rainbow, the mechanism used by neighbour coverage to deal with dead ends. The basic idea for avoiding connectivity holes is that of allowing the nodes to forward packets away from the sink when a relay offering advancement toward the sink cannot be found.

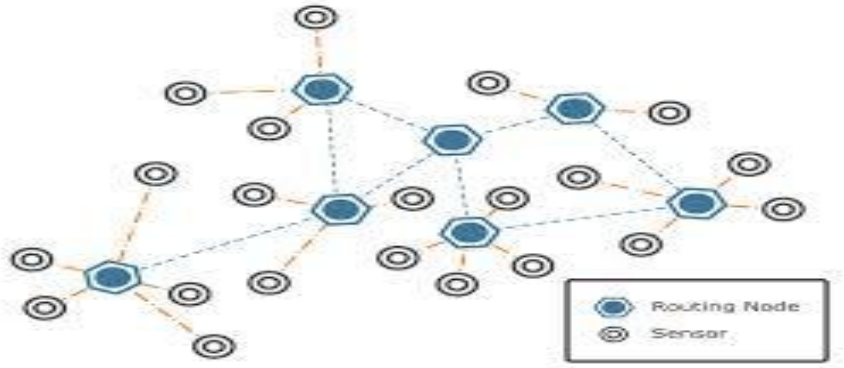

Figure 2: Placement of The Sensor in the WSN Topology through Cluster heads (Routing Nodes)

To remember whether to seek for relays in the direction of the sink or in the opposite direction, each node is labelled bay colour chosen among an ordered list of colours and searches for relays among nodes with its own colour or the colour immediately before in the list. Rainbow determines the colour of each node so that a viable route to the sink is always found. Hop-by-hop forwarding then follows the rules established by Neighbour coverage .Optimal position to route query to is given by

$$x_o = \arg_x[\nabla M_c = 0] \quad (2)$$

$$Mc = \gamma Mu - (1 - \gamma)\, Ma \quad (3)$$

The routing is directly addressed to the sensor node that is closest to the optimal position

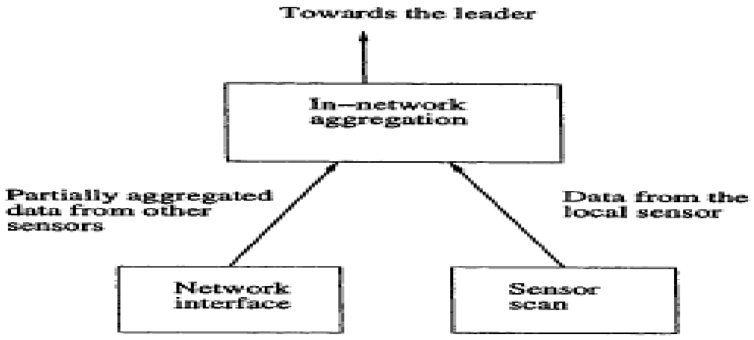

Figure 3: Query Plan at a Source Sensor

Views the network as a distributed DB where complex queries can be divided into several sub queries. The BS sends a query, which is then forwarded by each node receiving the query each node tries to respond to the query partially by using its preached information Triggered update obtaining information from all neighborhoods within a look-ahead of *d* hops Query is returned back to the querying node as a completed response.

4.1 Experimental Analysis:

We modify the source code of Minimum Cost Forwarding Algorithm (MCFA) in NS-2 (v2.30) to implement our proposed protocol. Note that the proposed NCPR protocol needs Hello packets to obtain the neighbour information, and also needs to carry the neighbour list in the RREQ packet. Therefore, in our implementation, some techniques are used to reduce the overhead of Hello packets and neighbour list in the RREQ packet, which are described as follows:. In order to reduce the overhead of Hello packets, we do not use periodical Hello mechanism. Since a node sending any broadcasting packets can inform its neighbours of its existence, the broadcasting packets such as RREQ and route error (RERR) can play a role of Hello packets. We use the following mechanism (Q.Huang,S.Bhattacharya,C.Lu,G.C.Roman, November 2005) to reduce the overhead of Hello packets: Only when the time elapsed from the last broadcasting packet (RREQ, RERR, or some other broadcasting packets) is greater than the value of Hello Interval, the node needs to send a Hello packet. In the interval of two close followed sending or forwarding of RREQ packets, the neighbour table of any node n_i has the following three cases:- if the neighbour table of node n_i adds at least one new neighbour nj, then node n_i sets the num_-neighbors to a positive integer, which is the number of listed neighbors, and then fills its complete neighbour list after the num_neighbors field in the RREQ packet. It is because that node nj may not have cached the neighbor information of node ni, and, thus, node nj needs the complete neighbor list of node n_i- if the neighbor table of node n_i deletes some neighbors, then node $n_i$sets the num_neighbors to a negative integer, which is the opposite number of the number of deleted neighbors, and then only needs to fill the deleted neighbors after the num_neighbors field in the

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RREQ packet;- if the neighbor table of node n_i does not vary ,node n_i does not need to list its neighbors, and set the num_neighbors to 0.

Table 1: Simulation Parameters Used to Build a Protocol

Simulation Parameter	Value
Simulator	NS2
Topology Size	1000m *1000m
Number of Nodes	50,100,150…
Bandwidth of the Network	4Mbps
Traffic type	CBR
Pause Time	25s
Packet size	512 bytes
Max speed	1 m/s
Min speed	5 m/s

The nodes which receive the RREQ packet from node n_i take their actions according to the value of num_neighbors in the received RREQ packet:- if the num_neighbors is a positive integer, the node substitutes its neighbour cache of node n_i according to the neighbour list in the received RREQ packet;- if the num_neighbors is a negative integer, the node updates its neighbour cache of node n_i and deletes the deleted neighbours in the received RREQ packet;- if the num_neighbors is 0, the node does nothing .Because of the two cases 2 and 3, this technique can reduce the overhead of neighbour list listed in the RREQ packet. (I. Stojmenovic, july 2002) in order to evaluate the performance of the proposed NCPR protocol, we compare it with some other protocols using theNS-2 simulator. Broadcasting is a fundamental and effective data dissemination mechanism for many applications in MANETs. In this paper, we just study one of the applications: route request in route discovery. In order to compare the routing performance of the proposed NCPR protocol, we choose the Dynamic Probabilistic Route Discovery [12] protocol which is an optimization scheme for reducing the overhead of RREQ packet incurred in route discovery in the recent literature, and the conventional AODV protocol. Simulation parameters are as follows: The Distributed Coordination Function (DCF) of the IEEE 802.11 protocol is used as the MAC layer protocol.

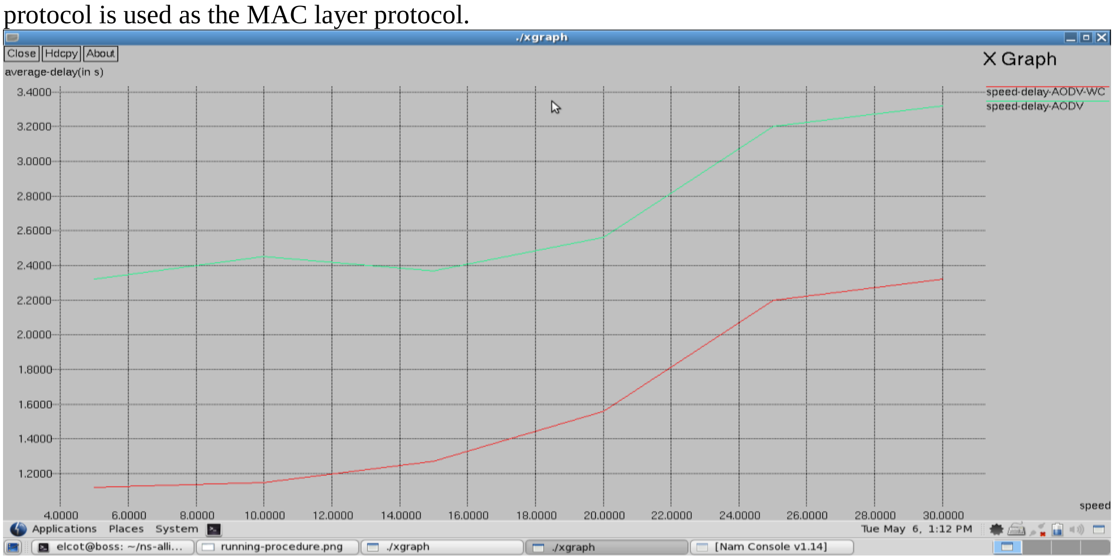

Figure 4: Simulation Output against Delay vs. Speed

Every source sends four CBR packets whose size is 512 bytes per second. The model is based on the random waypoint model in a field of 1;000 m _ 1;000 m. In this mobility model, each node moves to a random selected destination with a random speed from a uniform distribution [1, max-speed].After the node reaches its destination, it stops for a pause time interval and chooses a new destination and speed. In order to reflect the network mobility, we set the max-speed to 5 m/s and set the pause time to 0. The Max Delay used to determine the rebroadcast delay is set to 0.01 s, which is equal to the upper limit of the random jitter time of sending broadcast packets in the default implementation of Minimum Cost Forwarding Algorithm (MCFA)in NS-2. Thus, it could not induce extra delay in the route discovery. The simulation time for each simulation scenario is set to 300 seconds. In the results, each data point represents the average of 30 trials of experiments. The confidence level is 95 percent, and the confidence interval is shown as a vertical bar in the figures. The detailed simulation parameters are shown in figure 4.

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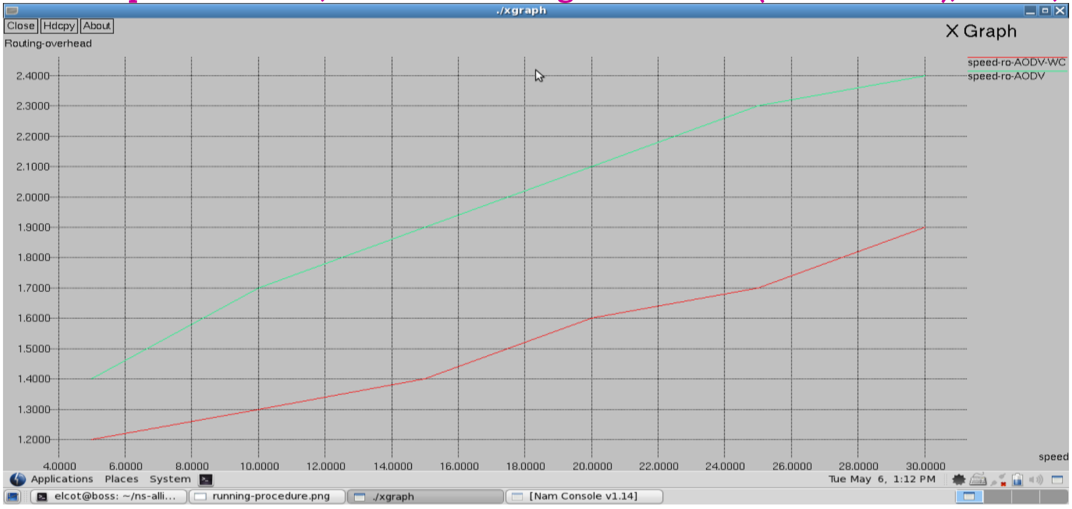

Figure 5: Simulation Output Against Routing Overhead vs Speed of Data Traversing

Thus evaluate the performance of routing protocols using the following performance metrics:

Routing overhead or Collision Rate: the average number of packets (including RREQ, route reply (RREP), RERR, and CBR data packets) dropped resulting from the collisions at the MAC layer per second.

Normalized Routing Overhead: the ratio of the total packet size of control packets (include RREQ, RREP, RERR, and Hello) to the total packet size of data packets delivered to the destinations. For the control packets sent over multiple hops, each single hop is counted as one transmission.

Packet Delivery Ratio: the ratio of the number of data packets successfully received by the CBR destinations to the number of data packets generated by the CBR sources.

Average End-to-End Delay: the average delay of successfully delivered CBR packets from source to destination node. The experiments are divided to three parts, and in each part we evaluate the impact of one of the following parameters on the performance of routing protocols: .Number of nodes. We vary the number of nodes from 50 to 300 in a fixed field to evaluate the impact of different network density. In this part, we set the number of CBR connections to 15, and do not introduce extra packet loss.. Number of CBR connections. We vary the number of randomly chosen CBR connections from 10 to 20 with a fixed packet rate to evaluate the impact of different traffic load.

Random Packet Loss Rate: Use the Error Model provided in the NS-2 simulator to introduce packet loss to evaluate the impact of random packet loss. The packet loss rate is uniformly distributed, whose range is from 0 to 0.1.

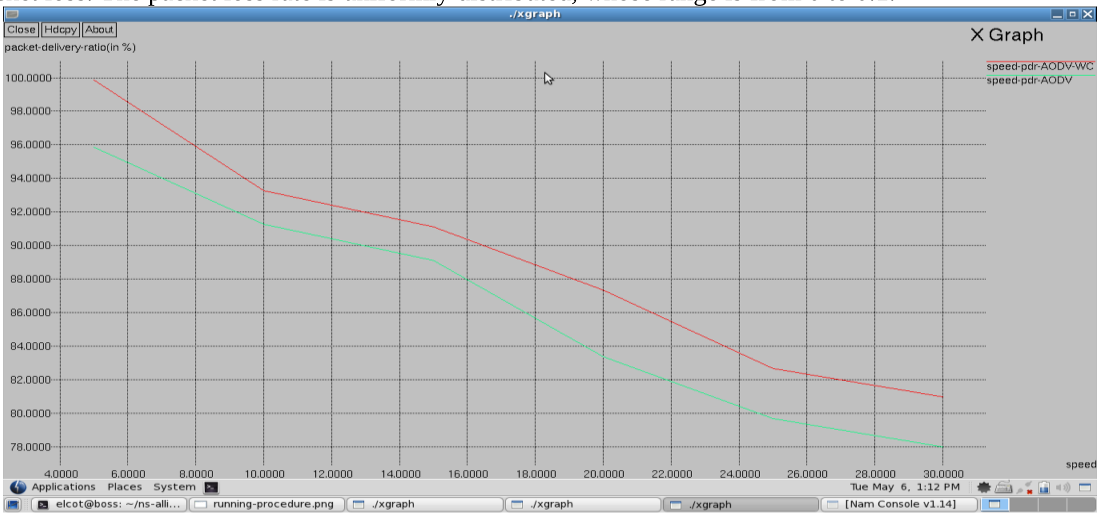

Figure 6: Simulation Output Against Packet Delivery Ratio and Speed

In this part, we set the number of nodes to 150 and set the number of connections to 15.In the experiments analysis, when two protocols are compared, we use the following method to calculate the average: we assume that the varied parameter is x_1; x_2; . . . ;x_n, the performance metric of protocol 1 is y_1; y_2; . . . ; y_3,

5. Conclusion:

In this paper, we proposed a probabilistic rebroadcast protocol based on neighbor coverage to reduce the routing overhead in WSN. This neighbor coverage knowledge includes additional coverage ratio and connectivity factor. We proposed a new scheme to dynamically calculate their broadcast delay, which is used to determine the forwarding order and more effectively exploit the neighbor coverage knowledge. Simulation results show that the proposed protocol generates less rebroadcast traffic than the flooding and some other optimized scheme in literatures. Because of less redundant rebroadcast, the proposed protocol mitigates the network collision and contention, so as to increase the packet delivery ratio and decrease the average end-to-end delay. The simulation results also show that the proposed protocol has good performance when the network is in high density or the traffic is in heavy load.

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