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Balanced Path Routing and Detection Mechanism for Wireless Sensor Networks

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ABSTRACT - An Enhanced Dijkstra's algorithm is presented in this paper. In this proposed approach, a new form of Balanced Path Routing technique is used in which the data send from source node is being transferred to the alternate node and then pass through the nodes to reach the destination. This prevents cuts in between the nodes and gives prior estimation of the shortest route path from source to destination. In Enhanced Dijkstra's algorithm, the packet delivery ratio is maintained at 80% even when the number of nodes gets increased. This finding indicates that proposed method guarantees reliable communication in wireless sensor networks. The simulation results show the best shortest path with better transmission time.

Keywords – Enhanced Dijkstra's Algorithm; Shortest path; Balanced Path routing mechanism

I. INTRODUCTION

Wireless sensor networks (WSNs) are a promising technology for monitoring large regions at high spatial and temporal resolution. A wireless sensor network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. 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, machine health monitoring, and so on.

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. Failure of a set of nodes will reduce the number of multi-hop paths in the network. Such failures can cause a subset of nodes – that have not failed – to become disconnected from the rest, resulting in a "cut". Wireless sensor network is composed of a powerful base station and a set of low-end sensor nodes. Base station and sensor nodes have Wireless capabilities and communicate through a wireless, multi-hop, ad-hoc network. The base stations are one or more components of the WSN with much more computational, energy and communication resources. They 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.

In our proposed mechanism, every node decides its path based only on local information, such as its parent node and neighbor nodes' routing information. . This mechanism ensures the prevention of data loss and enhances the time interval between the nodes. Enhanced Dijkstra's Algorithm outperforms the existing algorithms in terms of average end-to-end delay and delivered packet ratio without causing much overhead. The simulation results show the best shortest path with better transmission time.

II. RELATED WORK

In this section we discuss some previous work done in this field by some researchers as follows.

In [1] X.Yuan and A. Saifee, have proposed Localized quality of service (QoS) routing that use global network state information to make routing decisions. To achieve good routing performance, localized QoS routing must effectively select the predetermined set of candidate paths. The effective path selection algorithm must consider various factors, including path length and load balancing in the whole network.

In [2] Pushpalatha1, Dr.B.Anuradha2, proposed Dijkstra's algorithm that was used to find the routes between anchors. This paper proposes a Dijkstra's algorithm using the network connectivity information and the estimated distance information among the sensor nodes and find out the shortest path between the source node and destination node with low cost.

In [3] Feng Zeng, Lan Yao ; Zhigang Chen ; Huamei Qi introduce a distributed scheme for sink nodes to find K paths to each sensor nodes. Secondly, a shortest path-based algorithm is presented for the maximum set covers problem in wireless sensor networks.

The algorithm partitions all nodes into possibly maximum disjointed sets, and the nodes in each set have all targets covered while ensuring the network connectivity. In the proposed algorithm, when constructing a cover set, the key idea is to select a node joining into the set if it has the shortest path to the nodes which is already in the set.

In [7] A. Cerpa and D. Estrin proposes ASCENT algorithm and presents analysis, simulation, and experimental measurements. We show that the system achieves linear increase in energy savings as a function of the density and the convergence time required in case of node failures while still providing adequate connectivity.

In [8] Shilpa Mahajan1, Jyoteesh Malhotra proposed an energy efficient technique based on graph theory that can be used to find out minimum path based on some defined conditions from a source node to the destination node. Initially, a sensor area is divided into number of levels by a base station based on signal strength.

III. PROPOSED WORK

Multi-path routing is a routing technique that enables data transmission over multiple paths, is an effective strategy in achieving reliability in wireless sensor networks. However, multi-path routing does not guarantee deterministic transmission. This is because more than one path is available for transferring data from the source node to the destination node. A hybrid multi-path routing algorithm is proposed for industrial wireless mesh networks for improving reliability and determinacy of data transmission, as well as to effectively deal with link failures. The proposed algorithm adopts the enhanced Dijkstra's algorithm for searching the shortest route from the gateway to each end node for first route setup.

The enhanced Dijkstra's algorithm achieves first route setup, responsible for route exploration and maintenance. After the initialization of a network, the network manager applies the enhanced Dijkstra's algorithm to calculate the shortest path to each end node. In networks, all end nodes must send field data to the gateway. The gateway then exchanges management messages with all the end nodes. After the initialization of the network, the enhanced Dijkstra's algorithm is adopted for first route setup with low calculation complexity and low overhead. The operation is executed by the network manager rather than allowing each node to launch its own search process.

An industrial wireless network can be represented as a simple connected graph, G=(V, E), where V and E denote the set vertices and the set of edges, respectively. The simple weight of each edge is represented by the distance between two nodes, as the length of the edge g indicates the gateway in networks, and d (v) is the distance between g and node v. The enhanced Dijkstra's algorithm is presented works as follows:

During algorithm operation, each vertex is either in unlabeled or labeled state. Initially, d(g)=0 and d(v)=∞, the states of all vertices are unlabeled (lines 1–4). The Fibonacci heap stores all the vertices, and d(v) is the key of each vertex (line 5). The vertex v with the minimum key is extracted from the heap, and the state of v is converted into labelled (lines 6–8). For each edge (v, u), if the state of u is unlabeled and d (v) + d (v, u) is smaller than d(u), then d(u) is replaced by d(v)+d(v, u) and the key of u is modified accordingly (lines 9–14). This algorithm is performed repeatedly until the heap is empty. In this way, the shortest routes from the gateway to each node are discovered.

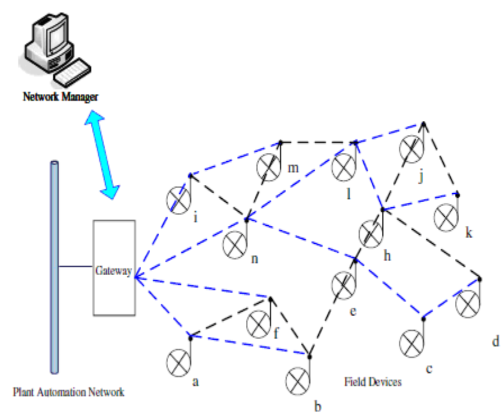

Fig.1 Wireless Network with first route setup

Multiple redundant routes for data transmission in networks are realized in this stage. This process extends available routing information to a mesh of multiple routes on the basis of first route setup period.

Once the first shortest route from node i to the gateway is found, the pheromone tables of all nodes along this route and the graph table of node i are populated. The pheromone on this route is a regular pheromone R^{g}_{ij}, and this route is added to graph table for data transmission.

$$R^{g}_{ij} \leftarrow \gamma R^{g}_{ij} + (1-\gamma)\left(c^{g}_{i}\right)^{-1}, \quad \gamma \in [0, 1] \tag{1}$$

SHORTEST ROUTE DISCOVERY PROCESS

Route exploration consists of two sub-processes, namely, pheromone diffusion and pheromone updating. Pheromone diffusion aims to spread the available pheromone information over the network by using periodic “keep-alive” messages. Pheromone updating aims to control and update pheromone information through route sampling.

Each node exchanges its information with neighbours using “keep-alive” messages. In the route exploration period, once a node obtains new information of routes to the gateway, the node sends “keep-alive” messages to its neighbours.

Pheromone Diffusion

During the process of pheromone diffusion, when node i receives a “keep-alive” message containing new route information from node j, then node i can derive the reported pheromone value w^g_j in eqn(2). This reported pheromone value indicates the goodness of the route from j to the gateway g and the locally maintained estimate of the cost c^j_i equals to the distance between nodes i and j. The resultant value of these two factors is called bootstrapped value B^g_{ij} in eqn(3) which is then used to update virtual pheromones or regular pheromones.

$$w^g_j = R^g_{jk} \cdot \frac{R^g_{jk}}{\max_{k \in N_j}\left(R^g_{jk}\right)} \quad (2)$$

$$B^g_{ij} = \left[\left(w^g_j\right)^{-1} + (1-\gamma)^{-1} c^j_i\right]^{-1} \quad (3)$$

Pheromone Updating

When a node receives a “keep-alive” message about route pheromone, the derived bootstrapped value initiates the pheromone updating of routes. There are two possibilities cases about pheromone updating: routes without regular pheromone and routes with regular pheromone. Corresponding to these two cases, the bootstrapped value can be used for route exploration and route updating, respectively.

a) *Route Exploration*

If only a bootstrapped value B^g_{ij} is present instead of a regular pheromone value in the pheromone table of node i, B^g_{ij} indicates a possible new route. However, this new route has never been sampled completely, so it is potentially unreliable. Thus, node i updates its pheromone information as follows: $V^g_{ij} = B^g_{ij}$. Once a virtual pheromone is assigned to a route, proactive forwards are sent out by the source node. During the advancing process, a proactive forward takes a new routing decision at the intermediate node m using the probability P^g_{im} in eqn (4)

$$P^g_{im} = \frac{\left(\psi^g_{im}\right)^{\beta_1}}{\sum_{j \in N_i}\left(\psi^g_{ij}\right)^{\beta_1}}, \psi \in \begin{cases} R & regular \\ V & virtual \end{cases} \quad (4)$$

b) *Route Updating*

If node i has a regular pheromone value in its pheromone table for the route from i to the gateway through j, then this route may have been sampled in the past or is considered the shortest route. Therefore, this route is reliable. B^g_{ij} is treated as an update of the goodness estimate of this reliable route and is used to replace R^g_{ij} when B^g_{ij} is better than R^g_{ij}. In this way, pheromones on current routes are kept up-to-date.

Route Selection for Data Transmission

When all the routes have regular pheromones, then the cycle of route exploration ends. However, for deterministic transmission, not all explored routes are used for data transmission. The network manager reserves top five routes for each node based on the pheromone values of routes. If node i does not have five routes, then all discovered routes are chosen for data transmission. Each of these top five routes is denoted by a graph ID, a regular pheromone value, and information regarding the next-hop node along this route. The information on these routes for data transmission is stored in graph tables of nodes along these routes.
Prior to each data transmission, node i choose the route whose graph ID is k from the graph table using the probability P^k_i, as shown in Equation (5). The pheromone value of this route is represented by P^k_i, while N_i^{Id} is the number of the graph IDs stored in the graph table of node i. The parameter β_2 controls the forwarding of data packet and is set at 5.

$$P^k_i = \frac{\left(R^k_i\right)^{\beta_2}}{\sum_{k=1}^{N_i^{Id}}\left(R^k_i\right)^{\beta_2}} \quad (5)$$

Modified Detection Mechanism

Once a node detects link failure for the next hop while moving or a message is received from its alternate neighbour node, it is indicated to all the upcoming neighbours in the network. This helps to update status of the node to the sensor nodes and then the alternate node starts its transfer by calculating the path length difference.

In this mechanism, multiple routing paths are used to transfer data. The key idea is that unless every path from a sensor node to a base station is broken by a failed node, data can be transmitted to base station.

This detection method can be implemented using the neighbor-based detection technique. Nodes will keep statistics of average signal strengths of received messages from their neighbors and compare them with the averaged value of these statistics.

IV EXPERIMENTAL RESULTS

- ***Simulation Situation 1(SS1)***

In this situation, all nodes work well and generate packets that flow to the gateway. The performances of Enhanced Dijkstra's algorithm is shown and based on the results it shows that we have better performance in average end-to-end delay when the number of nodes is increased. In particular, the packet delivery ratio in the Enhanced Dijkstra's algorithm is maintained at 80% even when the number of nodes gets increased. This finding indicates that proposed method guarantees reliable communication in wireless sensor networks.

Here, router 2 path is the shortest path with better transmission time when compared to router 1.

Router	Node	Sending path	Data Transmission Time (ms)
R1	Cluster node 2	N1-N5-N7	1670.328
R2	Cluster node 6	N1-N5-N8-N11	147.852

Table.1 Simulation Situation 1

The packet delivery ratio refers to the simulation situation 1.In this situation, Router1 has possible shortest path through node2 and Router2 through node6 randomly deployed in a square area with side length 10 units, respectively.

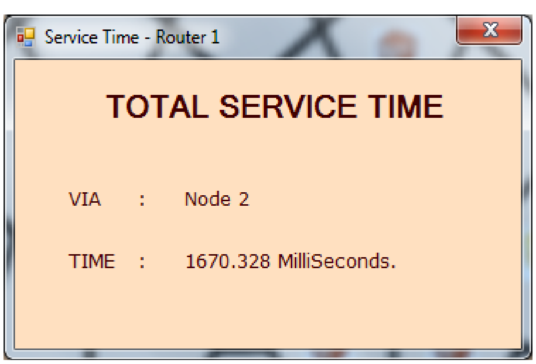

Fig.2 Router 1 Transmission Time in SS1

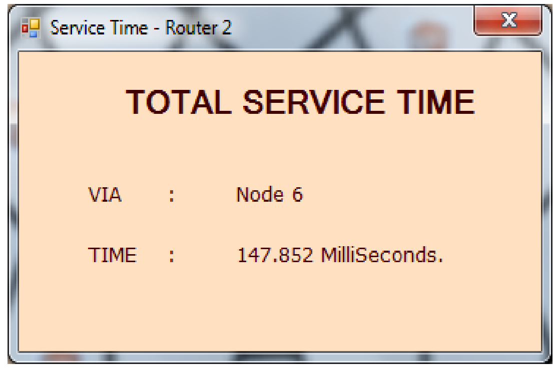

Fig.3 Router 2 Transmission Time in SS1

- ***Simulation Situation 2(SS2)***

The control environment is harsh in the industrial fields. Thus, the links between nodes may fail because of imminent external environmental factors or faulty nodes. To verify the effectiveness of route maintenance of the proposed algorithm another transmission of data is done and the transmission details are compared. With the route maintenance mechanism, Enhanced Dijkstra's ensures the reliability of routes and avoids unnecessary restarting route exploration.

Router	Node	Sending Path	Data Transmission Time (ms)
R1	Cluster node 4	N1-N14	639.36
R2	Cluster node 5	N1-N9-N13-N15	829.17

Table.2 Simulation Situation 2

In this situation, Router1 has possible shortest path through node4 and Router2 through node5 randomly deployed in a square area with side length 10 units, respectively.

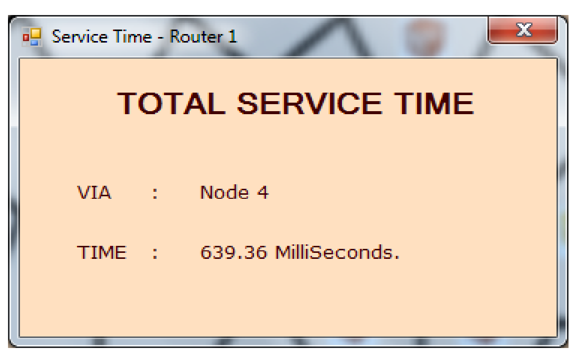

Fig.4 Router 1 Transmission Time in SS2

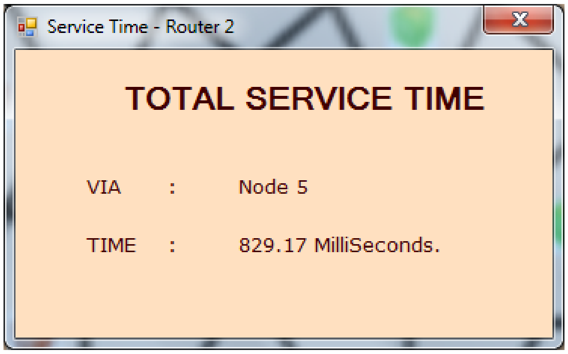

Fig.5 Router 2 Transmission Time in SS2

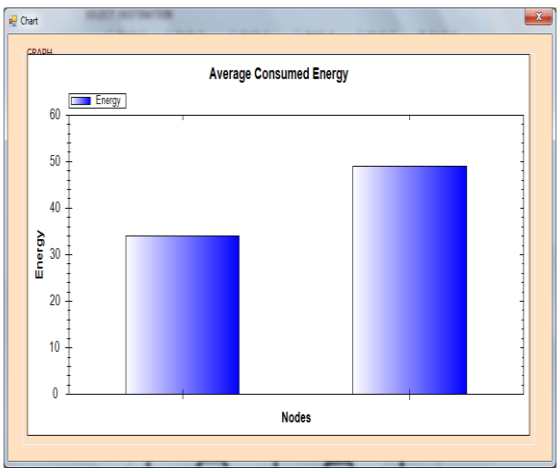

Fig.6 Transmission Time Comparison (ms)

In sum, Enhanced Dijkstra's algorithm outperforms the existing algorithms in terms of average end-to-end delay and delivered packet ratio without causing much overhead. Balanced path routing is more scalable because its performance advantage increases with number of nodes; moreover, it can cope with topological changes. Therefore, this proposed approach achieves reliable and deterministic transmission with low flooding problem

V CONCLUSION

The proposed algorithm adopts the enhanced Dijkstra's algorithm for searching the shortest route from the gateway to each end node for first route setup. The enhanced Dijkstra's algorithm achieves first route setup, responsible for route exploration and maintenance. In this mechanism, multiple routing paths are used to transfer data. This helps to update status of the node to the sensor nodes and then the alternate node starts its transfer by calculating the path length difference. In particular, the packet delivery ratio in the Enhanced Dijkstra's algorithm is maintained at 80% even when the number of nodes gets increased. This finding indicates that proposed method guarantees reliable communication in wireless sensor networks.

The proposed mechanism prevents the total energy of the nodes in the network and the range of communication is more efficient when compared with the earlier cut detection system. Thus, balanced path routing in wireless networks is an advanced mechanism for sensors with detection capabilities and notification node states to the alternate or neighboring during the data transfer. Although many of these routing techniques look promising, there are still many challenges that need to be solved in the sensor networks. The same work process can repeat in future work with various techniques to obtain accurate result than the proposed techniques

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