EFFICIENT ROUTING USING STR IN ZIGBEE WIRELESS NETWORKS

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ABSTRACT

The Zigbee tree routing does not require any routing table and route discovery overhead to send a packet to the destination, so it is widely used in many resource-limited devices and applications. Zigbee is based on IEEE Standard 802.15.4. Zigbee is a specification suite for a high-level communication protocols used to create Wireless Personal Area Networks (WPAN). Zigbee is frequently used in low data rate applications that entail long battery life and secure networking. In Zigbee network, to send the packet to destination it doesn't require any routing table and route discovery overhead. But the fundamental drawback of Zigbee is that the packet transmission follows the tree topology. Therefore, it cannot provide the most favourable routing path. The key idea of the shortcut tree routing is to calculate remaining hops from an arbitrary source to the destination using the hierarchical addressing scheme in Zigbee. Each source or intermediate node transmits a packet to the neighbor node, which has the remaining hop count to destination. The shortcut tree routing is completely distributed and compatible with Zigbee standard in that it only uses the addressing scheme and neighbor table without any changes of the specification. The efficient performance rating shows that the shortcut tree routing achieves better performance, when compared with Zigbee tree routing.

Index Terms : Zigbee, Tree Routing, Shortcut Tree Routing, Neighbor Table, Wireless Sensor Network, IEEE 802.15.4.

I. INTRODUCTION

Zigbee is one of the newest technologies developed by Zigbee Alliance. Zigbee is a typical wireless communication technology based on IEEE 802.15.4 standard which is widely used in wireless sensing networks. Zigbee is a specification for a suite of high-level communication protocols used to create WPAN which is built from small, low power digital radios. It is different from other Personal Area Network (PAN) such as Bluetooth, Wi-Fi. Zigbee devices uses the mesh networking to transmit data over long distances by passing through one or more intermediate nodes to reach more distant ones. Every node is assigned a unique 16-bit address dynamically using either distributed addressing or stochastic addressing scheme. The maximum data rate of Zigbee is 250 kbit/s, which is best suited for intermittent data transmissions from a sensor or input device.

The 802.15.4 standard was specifically designed for the purpose of wireless sensing applications. Due to flexibility it supports multiple data rates and multiple transmission frequencies. It requires less power because it allows the devices to be in sleep mode. Additionally, the rapid synchronization to the network can be achieved when the node wakes up from sleep mode. Applications include environment monitoring, wireless light switches, electrical meters with in home displays, military security, traffic management systems home automation, and other consumer and industrial equipment that requires short range low-rate data transfer. The technology defined by Zigbee specification is intended to be simpler and less expensive than other wireless personal area networks(WPANs) such as Bluetooth or Wi-Fi.

Zigbee is a Low Rate Wireless Personal Area Network(LR-WPAN). An LR-WPAN is a simple, low cost communication network that allows wireless applications with limited power requirements and maximum throughput. The main objectives of an LR-WPAN are reliable data transfer, ease of installation, long battery life and extremely low cost. Some of the characteristics of an LR-WPAN are Optional allocation of guaranteed time slots, Energy detection, Carrier sense multiple access with collision avoidance channel access, Completely acknowledged protocol to achieve reliability, low power consumption, Link quality indication.

The routing protocol in Zigbee is derived from AODVjr, which is one of the reactive protocols in Mobile Ad-hoc Network(MANET). Similar to other MANET routing protocols, Zigbee reactive routing protocol performs on-demand route discovery process and provides the optimal routing path for arbitrary source to destination pair. For each communication pair, route discovery process is required so it leads to route discovery overhead and high memory consumption. The route discovery process is flooded by all nodes in the network which leads to high collision and extra overhead.

On the otherhand, ZTR does not require any routing table and route discovery overhead. In Zigbee, network addresses are assigned using a distributed addressing scheme that is designed to provide every potential parent with a finite sub block of network addresses. Due to such addressing scheme, the system constructs a tree topology. However, a sender cannot know if the destination is located nearby, since tree routing concerns only about the parent and child relationship. Although the tree routing is efficient in the view point of memory usage, the routing cost is sometimes inefficient. This paper proposes the shortcut tree routing algorithm to achieve both memory efficiency and routing efficiency. The method proposed in this paper improves the ZigBee routing algorithm by using neighbor table, which is part of the existing ZigBee network specification.

II. RELATED WORKS

MANET routing protocols can be classified into proactive and reactive routing protocols. The proactive routing protocol every so often updates the topology changes in the routing table, so every routing table has the up-to-date routing path. The examples of proactive protocols are DSDV [4] and OLSR [3]. The proactive protocols cause routing table overhead. In DSDV [4], packets are transmitted between stations by using routing table. Each stations contains routing table which lists all available destination and hop count. In a dynamic varying topology, each station periodically updates the routing changes and transmit the updates to every other station. In OLSR [3], each node selects a set of its neighbor nodes as "multipoint relays" (MPR) is responsible for forwarding control traffic by reducing the number of transmissions required. This technique significantly reduces the number of retransmissions required to flood a message to all nodes in the network.

The example of reactive routing protocols are AODV [5], DSR [6]. In reactive protocols there is no routing table overhead, because the expired routing entry will be removed from the table. In AODV [5], **path discovery** process is initiated whenever one node needs to communicate with other node. The source node initiates the route discovery process by broadcasting RREQ messages to their neighbors. Each neighbor node satisfies the RREQ by unicasting RREP back to source or rebroadcast the RREQ to their neighbors. This procedure is repetitive until the RREQ packet reach the destination. For each communication pair it performs the route discovery. In DSR [6] Route discovery process can dynamically discover a route to any other host in the ad hoc network. The host initiating the route discovery process broadcast the ROUTE REQUEST packet to the host within wireless transmission range. In DSR, the each time transmitting the route discovery packet the source route will be added in the packet header. When transmitting the packet the entire route will be listed in the packet header. The reactive protocols cause route discovery overhead.

The reactive routing protocol in ZigBee is derived from AODVjr[2] (AODV junior), which is one of the representative reactive routing protocols in MANET. ZigBee reactive routing protocol provides the optimal routing path for the arbitrary source and destination pair through on-demand route discovery. AODVjr[2] removes the following items from the AODV specification.

- Sequence Numbers
- RERR
- Gratuitous RREP
- Hello Messages
- Hop Count and precursor lists

In this paper [2] it has been shown that AODVjr has nearly the same performance as AODV. AODV implementations predicted that AODVjr would take not more than half the time to program and debug when compared with a full AODV implementation.

The paper [10] discuss about the efficient flooding scheme is as follows: When a source node wants to flood a message, it computes a subset of its neighbors as forwarding nodes and attaches the list of the forwarding nodes to the message. Then, it broadcasts the message out. Upon receiving a flooding message, if the message has been received previously, it is deleted; otherwise, the message is delivered to their neighbor node listed in the forwarding list, or does not flood if it is the destination. The message will eventually reach all the nodes. These methods are discussed in three parts: 1) forwarding node selection, where a node selects a list of 1-hop neighbors to forward the flooding message, 2) forwarding node optimization, which further reduces the size of forwarding nodes by removing the nodes that are already covered, and 3) mobility handling, where each node incrementally updates its forwarding set in response to topology changes.

The paper [7] suggests utilizing the 1-hop neighbor table to reduce the routing cost of ZTR. The proposed STR algorithm chooses the neighbor node if it can reduce the hop count to the destination. Paper [17] shows that STR algorithm saves more than 30 percent of hop count compared with ZTR without any route discovery overhead. However, it is limited on estimating the saved hop count comparing with ZTR. In this paper, in addition to the ineffective routing path of ZTR [7], they have identified that ZTR suffers from performance degradation when all the packets are concentrated on the same tree links. Paper [7] demonstrate these problems of the ZTR by the network simulation, and prove that STR significantly improves the overall network performances such as end-to-end delay, packet delivery ratio, , path stretch and so on.

III. EXISTING SYSTEM

3.1 Zigbee Tree Routing

Every potential parent is provided with a finite sub-block of the address space, which is used to assign net addresses to its children. Given maxChildren (Cm), MaxDepth(Lm), and maxRouters (Rm), the function Cskip(d) computes the size of the address space distributed by each parent at depth d as follows:

$$C_{skip}(d) = \frac{1+C_m - R_m - C_m \cdot R_m{}^{L_m - d - 1}}{1 - R_m}$$

For example, the network address assigned for the kth router and nth end device by their parent at depth d as in the following equation.

$$A_k = A_{parent} + C_{skip}(d).(k-1) + 1 (1 \leq k \leq R_m)$$

$$A_n = A_{parent} + C_{skip}(d).R_m + n \ (1 \leq n \leq C_m - R_m)$$

A kth router that has positive Cskip(d) can distribute address spaces to its child nodes. Since every device in the arrangement is a descendant of the ZigBee coordinator and no device in the network is the descendant of any ZigBee end device, any device at depth d has the sink address D if the following equation is satisfied.

$$A < D < A + C_{skip}(d-1)$$

In tree routing, if the destination is at bottom, the device sends the data to one of its children; otherwise, it sends to its parent.

The tree routing protocol follows the parent child relationship. Even if the sender is within the one hop transmission range, the packets routed through several hop to reach the destination.

In ZTR the packet transmitted from the source node goes up to the root node following the parent node, and then travels back to the destination. Even the destination is within the one hop transmission range, it routes through multiple hop. So the routing overhead of tree routing algorithm cannot be avoided if it follows parent-child relationships. In order to overcome such problem, each node should take its neighbor nodes as the next hop nodes.

(1a) (1b)

Fig. 1 Tree Routing

Fig. (1a) the packet is routed through several hops toward the destination even though it is within the transmission range. This problem is called **detour path problem**. The packet traversed from the source node goes up to the root node following the parent node, and travels back to the destination. In this way, 4 hops are required to obtain the destination. To solve this detour path problem of ZTR, ZigBee specification use the direct transmission rule that allows a coordinator or a router to transmit a packet directly to the destination is indicated as the green color arrow if the corresponding destination is in the neighbor table.

In case that the destination is located more than 2-hop distance away from a source node, the direct transmission rule is not valid. In addition to the **detour path problem**, it has the **traffic concentration problem** due to limited tree links. In Fig. (1b) all the packets pass through only common root node, which leads to severe congestion and collision of packets.

IV. PROPOSED SYSTEM

4.1 Shortcut Tree Routing

STR is proposed in this paper [8] and [12] to enhance the routing of Zigbee. The routing overhead of tree routing algorithm cannot be avoided if it follows parent-child relationships. STR improves existing ZigBee tree routing by using the **neighbor table**. The neighbor table is defined in the ZigBee specification, so there is no need to search for the neighbor list. The STR basically follows ZigBee tree routing algorithm, but chooses one of the neighbor node as next hop node if the routing cost to the destination can be reduced. In order to choose the next hop node, the remaining hop count is calculated from the next hop node to the destination which will be computed for all the neighbor nodes including parent and children nodes.

The working of STR is explained as follows. Initially the source node finds all neighbor node using neighbor table, among all neighbor nodes it chooses one of the neighbor nodes as the next hop node. The next hop is choosen based upon the remaining hop count. The remaining hop count is calculated for all neighbor node to destination. Then it chooses the path with minimum hop count and transmit packet. This process is repeated until reaching the destination.

The algorithm to find the next hop node for a given destination address

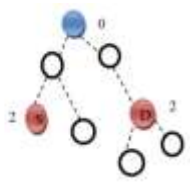
1. Initialize minimumRouteCost with infinity.
2. Find ancestor for destination address
3. For each neighbors in the neighbor table.
4. Find ancestor
5. If LCA
6. Calculate RouteCost using the below formula

RouteCost = level(dstAddr) + level(neighborAddr)
- 2*level(LCA)

7. Else increment LCA and find LCA
8. If RouteCost is less than minimumRouteCost
9. Then the nextHop is neighborAddr
10. Transmit packet to nextHop.

The root of the common sub-tree that contains address of both neighbor node and destination which is called the least common ancestor (LCA) [9]. The blue colored node is the root of the highest level common sub-tree called LCA, and the number indicates its tree level. Using this reference level, the remaining hop count is calculated using the equation

Route Cost = (Level of source address) + (level of destination address) – (2 * level of Least Common Ancestor)



Route cost = 2 + 2 – 2 * 0 = 4 **Fig. 2 Routing Cost Calculation**

In ZTR the packet is transmitted to the parent node which contains the destination address and then transmitted to the destination. The proposed algorithm STR computes the routing cost in the same way as ZTR.

4.2 Neighbor Table

Each device in ZigBee maintains a neighbor table which contains all the 1-hop neighbor information within the transmission range. The neighbor table includes the node's extended address, network address, network's PAN

ID, device type and relationship. Optionally, additional information such as depth , beacon order or join permit can be included.

Entries in the table are created when the node joins to an existing network and removed when the node leaves the network. When a joining node requests a NLMENETWORK- DISCOVERY, the already joined nodes response the new node by transmitting beacons. The newly joined node stores neighbors information from the information contained in beacon packets. Conversely, when the node leaves the network, the entry is removed from the neighbor table. Nodes can know this information by receiving NLME-LEAVE. indication messages. Every time a device receives any frame from some neighbor node, the neighbor table is updated and said to be up-to-date all the time.

V. EXPERIMENTAL RESULTS

The experimental results are discussed briefly about the Node creation, Address assignment, Next hop Selection and Packet transmission. The IEEE standard used for Zigbee is 802.15.4. This IEEE standard must be configured in the coding part as MAC address.

The network layout of the zigbee wireless network at the initial stage before the simulation results starts will look as follows:

Fig. 3 Node Creation

Three types of nodes are created, they are Co-ordinator, Router and End Devices. In Zigbee network the sensor nodes are fixed statically in equal distance. The sensor nodes collects information and passes to the coordinator.

Fig. 4 Address Assignment

Cm represents the maximum children node and lm represents the maximum depth and Cskip represents the size of the address space. For each node, addresses are dynamically assigned.

Node 0 is the PAN Coordinator node similar to base station which is represented in red colour. The blue color node represents the router node while the green color node represents the end device. The sensor nodes collects the information and passes to the co-ordinator.

The router can communicate with both co-ordinator and end devices, which acts as the intermediate node between source and destination. The end devices can only communicate with router and can transmit or receive the packets through intermediate nodes.

Fig. 5 Next Hop Selection

A source or an intermediate node selects the neighbor node as the next hop, which has the minimum remaining hop count to the given destination, and then transmits a packet to the next hop node.

The source node is 7 and destination is 10. The next hop is choosen based upon the remaining hop count. The remaining hop count is calculated with source, least common ancestor and destination. Each time the routing cost is calculated for all neighbor node to destination and chooses one of the neighbour node as the next hop with minimum hop count and then transmit packet. The same process is repeated until reaching the destination.

Fig. 6 Packet Drop

During transmission the packet may get drop due to link failure or nodes energy level may get decreases. At that time the node may not send or receive the packet.

Fig. 7 Choose next hop with next minimum hop count

So the node chooses the another next hop node, with next minimum hop count which is calculated based on the same routing cost equation from another neighbor node to destination and then transmit packet.

VI. PERFORMANCE EVALUATION

STR is evaluated in varied metrics of the routing performance. The evaluation of the routing performance includes hop count, end-to-end delay, packet delivery ratio. In this evaluation, the network simulator NS-2 and IEEE 802.15.4 MAC protocols are used for comparing STR and ZTR. The number of nodes used in the simulation parameter is 20 to 100. In this simulation, the position of co-ordinator must be in the center. The propagation model used in the simulation is Two-ray propagation. The maximum transmission range between each sensor node is 25 m. The network configuration for Cm and Lm is 4 and 3 respectively. Both of a source and a destination are randomly chosen and traffic patterns used in this simulation is 20.

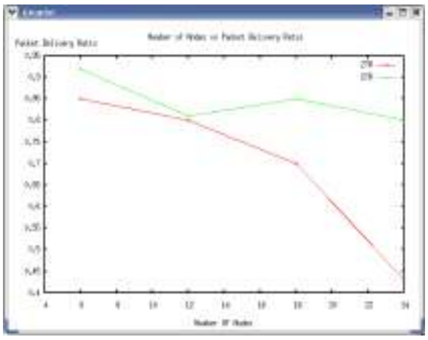


Fig. 8 Packet Delivery Ratio

Packet delivery ratio is the ratio of the number of data packets successfully arrived in the CBR destinations to the number of data packets generated by the CBR sources. Packet delivery ratio is calculated with increasing number of nodes. STR achieves the high packet delivery ratio when compared with ZTR.

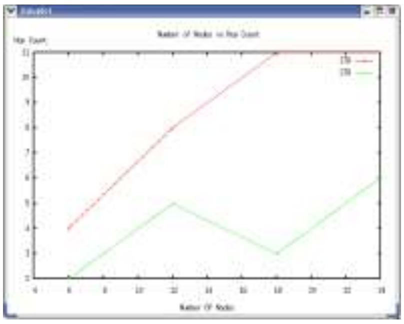


Fig. 9 Hop Count

Hop Count is the metrics used for measuring the routing cost between source and destination. STR achieves the minimum hop count when compared with ZTR and saves the hop count of ZTR.

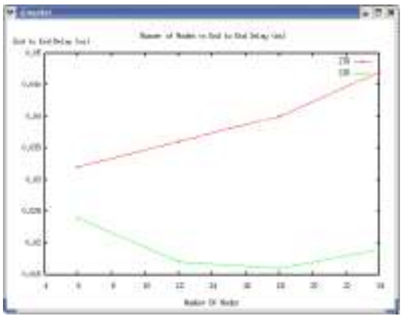


Fig. 10 End to End Delay

End-to-end delay is the average time difference between the sent time of data packet by the source node and the successful reception time by the destination node. The delay is increased in ZTR while STR achieves the better performance when compared with ZTR.

In ZTR the packet delivery ratio decreases with the number of nodes and number of traffic patterns.STR achieves the high packet delivery ratio when compared to ZTR. In ZTR, the number of hop count increases with the number of nodes and number of traffic patterns. STR saves the hop count when compared with ZTR. The delay is also high in ZTR due to choosing longest path but STR reduces the delay when compared with STR. But the memory consumption of STR is high when compared to ZTR. Due to high memory consumption the overhead of STR is high when compared with ZTR.

VII. CONCLUSIONS

In this paper the detour path problem and traffic concentration problem of ZTR are identified. To overcome these problems, STR is proposed to enhance the routing of ZTR by using neighbor table. Based on the remaining hop count to the destination the optimal next hop node is choosen. The mathematical analyses prove that the 1-hop neighbor information in STR reduces the traffic load concentrated on the tree links as well as provides an efficient routing path. STR achieves the better performance by saving the routing cost of ZTR. In future work, steps are taken to reduce the packet failures by choosing the power nodes with high energy level and transmitting the packet through these nodes will increase the packet delivery ratio.

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