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To improve the network lifetime using Distributed Throughput Optimization for Zigbee cluster tree networks

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Abstract

Zigbee is a low rate, less complex and low power consuming communication standard of IEEE802.15.14.Zigbee is used for connectivity of low rate WPAN ,Portable and mobile devices. Out of the different topologies Zigbee cluster-tree is most suitable for the LR-WPAN. This topology supports light weight routing and power saving operations. In this paper we are addressing two major issues of a WSN that is Maximum bandwidth utilization using the vertex constraint maximum flow approach and the second is the throughput optimization using the PPR Algorithm. The results of the simulation clearly shows the improvement in the network lifetime due the proposed PPR algorithm over the existing approaches.

Keywords: Zigbee, PPR Algorithm, Vertex constraint maximum flow problem.

1. Introduction.

In today's world of wireless network and mobile devices the wireless communication standard Zigbee has a great importance. This removes the constraints of physical wiring and thus reduce the installation cost. Like WIFI and Bluetooth Zigbee is based on IEEE 802.15.14 and has radio Bandwidth of 2.4Ghz internationally and 868Mhz or 915Mhz in specific parts of the world. The advantages of Zigbee like low power consuming, less complex hardware and low cost which is suitable for any LR-PAN makes it more favorable for wireless control applications. Zigbee can accommodate over64000 nodes. There are three different topologies in which zigbee operates ; Star ,Mesh and Tree.

1.1. Layers of Zigbee

Zigbee is a very well-known wireless communication standard used for establishing a communication between various wireless and portable devices in a wireless network. It is best suitable for LR-WPAN due to the advantages of it simple design and power efficiency. So the wireless network based on zigbee has long battery life. Today the concept of home automation is become so real and common just because of the existence of this communication standard. IEEE 802.15.4 has four different layers Physical layer, MAC layer, Network layer and application layer's. Of these the Physical and MAC layer specifications are described by the Zigbee protocol stack.

Zigbee has three different topologies; Star, Mesh and Tree. But the cluster tree is most suitable for the LR-WPAN as it supports power saving process and light weight routing. Light weight routing is based on the distributed address assignment policy. Though cluster tree topology is most suitable for Zigbee there are certain problems like in a tree structure the failure of a single tree leads to the failure of the entire network and the recovery will involve a lot of communication overheads. Also this topology is not making the full use of many available routing paths. Thus there is no maximum utilization of the available bandwidth. Also certain areas of the network require more investigations as compared to the others which generates a sudden traffic in the network which cannot be handled by the cluster tree network. Thus the Zigbee cluster tree topology not being able to manage the heavy traffic it will adversely hamper the data delivery.

In this paper we propose a distributed adoptive parent (DAP)based framework for zigbee cluster tree topology. this easily handles the varying traffic issues in the network at any given instant. It also provides the flexible routing and it increases the bandwidth utilization without violating the Zigbee standards. The DAP framework allows the Zigbee node to demand for extra bandwidth from its adjacent routers(adoptive parents)along with the original parent router in case of heavy traffic.

2. ZIGBEE ARCHITECTURE

The IEEE standard, 802.15.4, defines the physical layer and medium access control sub layer for low-rate wireless personal area networks (LR-WPANs). IEEE 802.15.4defines a superframe structure that begins by transmitting a beacon issued by a PAN coordinator. The process consists of an active portion and an inactive portion. The coordinator and devices can communicate with each other during the active period and enter a low-power phase during the inactive period. The active portion with 16 time slots is comprised of three parts: a beacon, a contention access period (CAP), and a contention free period (CFP). The beacon is transmitted by the coordinator at the beginning of slot 0, and the CAP follows immediately after the transmission. During the CAP, devices can transmit non time-critical messages and MAC commands. In the CFP, the standard protocol provides a Guaranteed Time Slot (GTS) mechanism that ensures the devices can occupy the time slots exclusively for transmission. For those devices that desire guaranteed time slots in the next superframe's CFP, they send GTS requests to the coordinator during the current superframe's CAP. Then, the coordinator checks if there is available bandwidth in the current superframe, and determines, based on an FCFS fashion, a device list for GTS allocation in the next superframe. Finally, the GTS descriptor is included in the subsequent beacon to announce the allocation information.

ZigBee , which is based on the IEEE 802.15.4 standard, defines the network (NWK) layer and the application layer (APL) in the protocol stack. There are three types of device in a ZigBee network: a coordinator, a router, and an end device. A ZigBee network is comprised of a ZigBee coordinator and multiple ZigBee routers/end-devices. The coordinator provides the initialization, maintenance, and control functions for the network. The router has a forwarding capability to route sensed data to a sink node.

The end device lacks such a forwarding capability. ZigBee supports three kinds of network topology, namely, star, cluster-tree, and mesh topologies. In a star network, multiple ZigBee end devices connect directly to the ZigBee coordinator. For cluster-tree and mesh networks, communications can be conducted in a multihop fashion through ZigBee routers. In a cluster-tree network, each ZigBee router with its surrounding devices is regarded as a respective cluster, and each cluster operates individually as a star network, as shown in Fig. 1. In this project, we assume that sensed data in ZigBee cluster-tree networks is delivered by the GTS mechanism because a high-delivery ratio can be guaranteed.

3. Throughput optimization using Adoptive parent based framework.

For the cluster tree network to handle the varying traffic, we make use a method called as Adoptive parent based network. In this method the Zigbee router is allowed to borrow extra bandwidth from its neighboring routers along with their original parent routers. Hence the requirement of extra bandwidth is met and the cluster tree network is able to meet the accurate data delivery.

3. Vertex Constraint Maximum Flow Problem.

A vertex-constraint flow network can be formulated as a directed graph G = (V,E) where V represents the routers in the network and E represents the possible communication links between pairs of routers. In a traditional flow network, each edge has a nonnegative capacity. By contrast, in a vertex-constraint flow network, each vertex u € V is associated with a nonnegative capacity, denoted by c(v)>= 0, which represents the GTS capacity of the router. Each directed edge (u,v) is associated with an implicit capacity c(u,v) = ∞; if (u,v) € E; otherwise, if (u,v) does not belong to E;, then c(u,v) = 0. For each flow, two vertices are distinguished in the network: a source s and a sink t, where s is the sender of the data that requires additional bandwidth and t is the data receiver. A flow in a vertex-constraint flow network G with respect to a source s and a sink t is a real-value function f: V x V → R that satisfies the following three properties:

Capacity constraint: P

∑u € V {(u,v) | f (u,v) > 0} <= c (v) ; ¥ v € V

Skew symmetry:

F (u,v) = -f (v,u) ; ¥ u,v € V

Flow conservation:

∑u € V f(u,v) = 0; ¥v € V – {s ,t}

The quantity f (u, v), which can be positive, zero, or negative, is called the net flow from vertex u to vertex v. The capacity constraint, which relates to a router's physical resource usage, stipulates that the net flow passing through, the router must not exceed its capacity. Because of the skew symmetry property, the net flow from one vertex to another vertex is the negative of the net flow in the opposite direction; and because of flow conservation, the total net flow into a vertex, except the source or sink is equal to zero. The value of a flow f is defined as the total net flow into the sink, A maximum flow is a flow of maximum value. In the vertex-constraint maximum flow problem, given a vertex-constraint flow network G with source s and sink t, the objective is to find a maximum flow f from s to t in G.

4. A Distributed algorithm.

We propose a distributed algorithm to resolve the vertex-constraint maximum flow problem. The algorithm is named as PPR algorithm (PULL PUSH RELABEL algorithm). This algorithm contains three types of solutions to balance the traffic in the network. In this method, if the node u is overflowing with high traffic rate, then it looks for the possible successor node to handle the excess traffic. If the successor is found, then its height is determined. (The direction of the successor node from current node)If the current node's height is lower than the successor node, then the current node initiates PULL the traffic into successor. If the height of the current node is higher than the successor node, then the PUSH method is initiated to push the traffic to the successor. If the successor and current node are in the same height, then the RELABEL is initiated and either successor or current node increases its height and perform PULL or PUSH based on the height. This PULL PUSH RELABEL method considerably handle the excess traffic occurred in the network. So the throughput of the network is considerably increased and communication could not be interrupted.

a. Pull Algorithm.

C_f (u,v) = c(u,v) - f(u,v) Where c(u,v) is 0 or ∞

C_f (u,v) = ∞ …………… [if u,v ϵ E]

C_f (u,v) = -f(u,v)………. Otherwise

Height function determines the direction of flow.Let h(s) = V & h(t) is the height function of source and sink &h(u) ≤ h(v+1)

b. Push Algorithm.

In a PUSH(u, v) operation, a higher vertex u pushes the over pulled flow back to a lower vertex v along the edge (v,u) ϵ G (G: network)

CONDITIONS: e(u)>0;c(v,u)≠∞;

ĉf(u,v)>0; h(u)=h(v+1)

f(u,v) ← f(u,v) + δ

f(v,u) ← -f(u,v)

e(u) ← e(u) - δ

e(v) ← e(v) + δ

c. RELABEL algorithm.

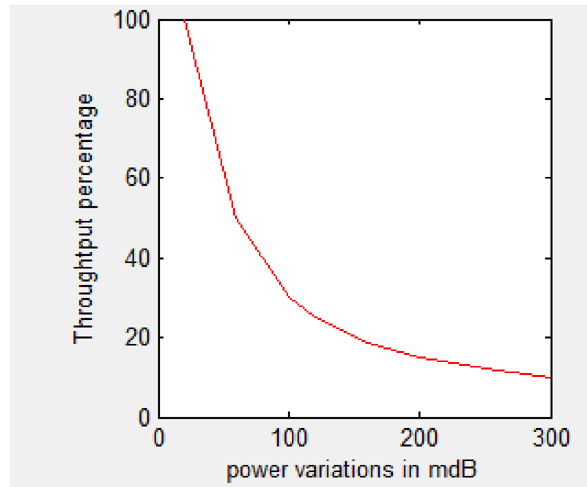
When the flow cannot be pushed or pulled we make use of Relable

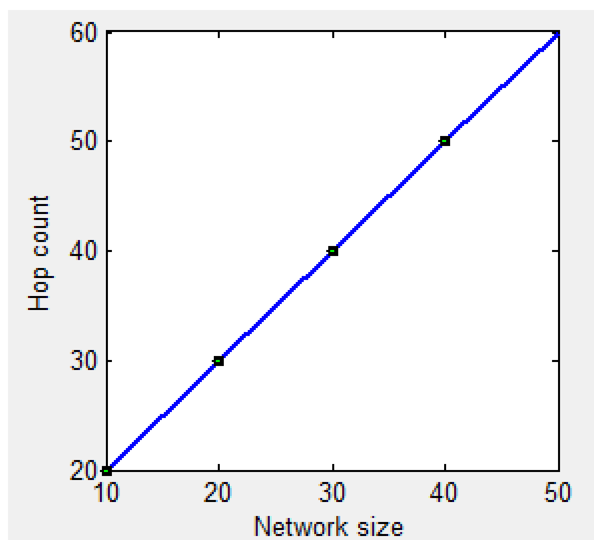
A RELABEL(u) operation enables a vertex u to increase its height.

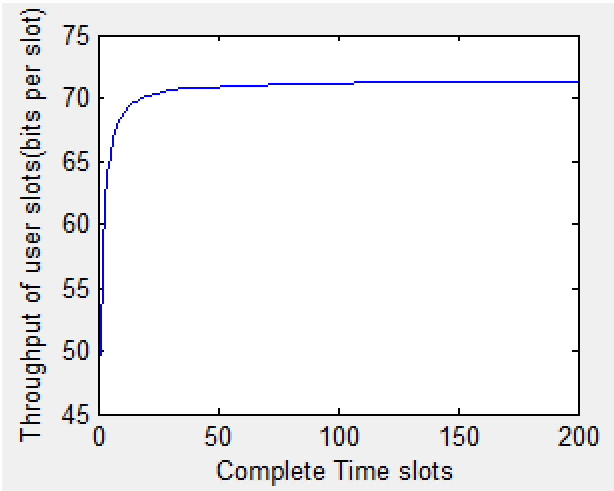
If e(u) > 0, and (u, v) ϵ E_f then h(u) ← 1+ min{h(v)|(u,v) ϵ E_f }…… E_f is residual function.

5. Results and Conclusion

In this paper, we have proposed an adoptive-parent-based framework for a ZigBee cluster-tree network to increase the bandwidth utilization without incurring any extra message exchange. Under the framework, a throughput maximization problem, called the *vertex-constraint maximum flow* problem, is formulated, and a distributed algorithm that is fully compatible with the ZigBee standard is proposed. The theoretical analysis proves that the proposed algorithm can provide an optimal solution, and the results of simulation experiments demonstrate a significant performance improvement over the original approach.







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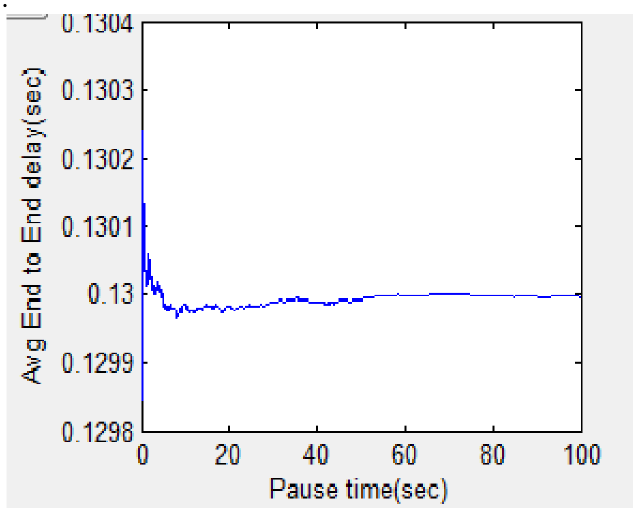

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