IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
ISO 3297:2007 Certified
Vol. 5, Issue 7, July 2016

Congestion Free Topology for Route Management in WSN Using K-Map

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Abstract: In the field concerning the wireless sensor network, the constraint of energy dissipation plays a very crucial role in determining the overall performance efficiency of the system. The main consideration criterion for any wireless network is the topology of that network. The topology considered in the proposed work is the CATree topology which uses Kmap technique to reduce the distance map between the nodes. A comparative analysis is performed considering different topology such as star topology and mesh topology with respect to CAtree topology. The evaluations of the proposed system is performed with respect to network throughput, packet delivery ratio and energy dissipation.

Keywords: CATree, Congestion Avoidance, K-Map, Packet Retransmission, Wireless Sensor Network.

I. INTRODUCTION

WSNs (Figure 1.1) are the field of prodigious interest today. Every sensor node is distributed among all the available area in the network. Sensor nodes usually sense, compute and send the data to one of the main location. Using the sensor generated data; one can monitor physical and environmental conditions at different locations. For any sensor node to transmit, receive, process and forward data, battery is necessary. Charging/replacing the battery is generally not achievable. Hence the primary objective in WSN design is therefore minimizing the battery consumption and increasing the network lifetime of a sensor node.

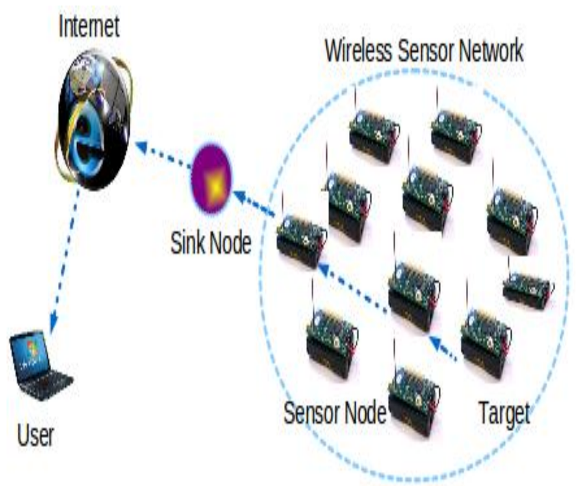

Figure 1.1: Typical Wireless Sensor Network [9]

In WSN's 'N' number of sensor nodes are transmitting the data at any instant in time to one or more sinks by taking multiple hops in the network. Whenever an event occurs in WSN, there requires a high rate to accurately depict the condition by generating sufficient data. Network congestion may occur in both proactive as well as reactive networks due to numerous aspects like buffer overflow in the sensor node, concurrent transmissions and dynamically varying channel environments. Typically, congestion occurs due to overflow in the buffer leading to dropping of packets excessively. Other reasons for congestion is collision and drop of packets in the network. Since dropped packets needs to be retransmitted, the overall congestion inside the network still increases thereby the collision may increase exponentially. The retransmission phenomenon (Figure 1.2) happening in a sensor node results in delay and the reduction in overall network lifetime.

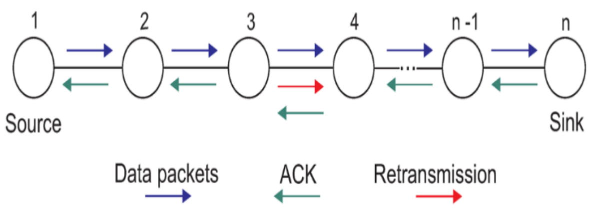

Figure 1.2 Packet Retransmission Phenomenon [2]

Collision can happen in two areas in the network: link level and node level. Link level collision deals with the collision inside a network due to bandwidth requirement, rate unavailability etc., whereas a node level collision deals with collision due to buffer overflow in a sensor node. In both cases, the overall battery consumption is more resulting in fast draining of battery and the probability of the sensor node getting dead is more. Hence energy consumption inside a WSN should be minimized to make a sensor node to operate for more time increasing the network lifetime.

Network congestion occurs in wireless sensor networks because it consists of thousands of sensor nodes which are sending the sensed data undergoing single or multiple

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hops to their respective client(s). Each sensor may send data to a single client or to multiple clients. Proactive networks send data continuously at regular intervals. Reactive networks send data at dynamically adapted rate. Network congestion occurs in both case due to the limited amount of rate which are available for transmission and reception; concurrent transmission from many clients resulting in packet collision; retransmissions due to packet loss. Congestion also occurs when the buffer overflows and more packets have to be dropped. Another main reason for congestion is that the nodes can transmit as many packets as they can, resulting in corruption of packets and collision inside the networks. Corrupted packets must be retransmitted thereby increasing the collision ratio. Collision increases the latency resulting in excess battery consumption.

II. RELATED WORKS

In a wireless sensor network (WSN), huge amount of traffic is generated when the event is detected. It is the period where the information generated by the sensor is very important and the congestion is very likely to appear in the network. The biggest challenge in that time is to detect and control/avoid the collision inside the network. In this section, the works related to avoiding the congestion in the network is summarized briefly under the subcategories.

A. Rate Reservation Mechanism

Many works have been done related to reporting the rate to avoid the collision inside the network. The main difficulty is to determine the accurate amount of rate to be reduced [1] by the upstream sensor nodes when there is a congestion occurred & reported by the downstream sensor nodes. Additive increase - Multiplicative Decrease (AIMD) [2] deals with adapting the rate periodically. It is very difficult to adapt rates quickly according to the environmental changes and no work exists regarding the same until today.

B. Works Related to the Medium Access Control (MAC)

Usually, WSN tries to solve the problem in the MAC layer. MAC protocols help sensor nodes to decide when & how to send the packets across the channel. The challenge is in making the decision on when to access the channel. Controlling the number of retransmissions [3][5] that can be occurred in each wireless link reduces significant amount of congestion in the network. The problem at network layer by proposing new routing mechanisms that considers the sleep state of some nodes should be addressed. The RTS/CTS handshake mechanism eliminates the hidden terminal problem but introduces a new problem called exposed node problem. Moreover, RTS/CTS handshake mechanism assumes symmetric channels [4] and is only applicable for point-to-point communications. This kind of mechanism is impracticable in wireless sensor network where the broadcasting and the presence of asymmetric links are very common.

C. Works Related to Congestion Control in the Transport Layer

There are many energy efficient congestion control mechanism for sensor networks are presented at transport layer. In COllision Detection and Avoidance (CODA) [5] protocol where every node inside the network, detects congestion by simply monitoring the buffer threshold level and the utilization of channel. It then broadcast back the signal messages to the source, and the source may change its sending rate or the neighbouring nodes may drop packets. Reliable MultiSegment Transport (RMST) [6], provides the reliable data transfer, guaranteed delivery and fragmentation/ reassembly of data packets greater than the network Maximum Transmission Unit (MTU). RMST provides guaranteed delivery and fragmentation/ reassembly for applications that require them. In all the above stated mechanisms, no works have been done considering the priority in the node and only some protocols consider the cross layer [7] interactions.

III.PROPOSED SYSTEM

This paper proposes a congestion free multi hop rate reservation and route management mechanism which selects the best path in the wireless sensor network. WSNs usually contain much number of nodes which are sensing the data and reporting the same to the specified main location. When an event occurs in the WSN, it is the time where the sensor nodes are active and are transmitting the data, the network becomes busy leading to collision in the network, packet drop occurs, packet corruption may occur, and when the packet is lost in the network, retransmissions should be performed. There are some situations where some external links are extensively used and some are optimally utilized and some links which are not used at all. For a network to be optimally utilized, consideration of the link matters most. The rate at which a link can transmit the data is also one of the major consideration while designing a wireless sensor network. This paper describes the novel strategy for selecting the best route in the network considering the packet reach time to the destination and assigning the priority to the packets.

Sink node maintains the relationship between the neighbour node considering the distance from the neighbouring node to itself and the rate at which the neighbouring node can transmit data on the link at that time. It uses Euclidian distance [8] formula to compute the distance between the nodes. Consider that source and destination nodes are placed at points (x1, y1) and (x2, y2) respectively then the distance‘d’ between the two points is computed as:

$$d=\sqrt{(x2-x1)^2+(y2-y1)^2} \quad [8]$$

A. KMap and Kgraph of sensor nodes

This subsection provides a brief overview of how to create a Karnaugh map or KRM of sensor nodes. It also defines how to construct a Karnaugh/KRG from KRM.

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The orthodox KRM is a mechanism to simplify the Boolean expressions. The Boolean results are transferred to a 2D grid from a truth table. Each position of cell represents a combination of inputs. The value inside a cell represents the output. A z-variable KRM comprises M=2z minterms (x0, x1,…, xM-1). The total size of network is equivalent to M.

The KRM of sensor nodes are a little unlike. If there are M no. of sensor nodes in the network, it can be represented as the z-variable KRM having M sensor nodes and z={lgN}. Minterms becomes the sensor nodes and the size of the KRM becomes the size of network M. All the cells are occupied by the nodes based on the association request from the sink. The guidelines for grouping the cells are same as the rules for simplifying the Boolean expressions. All the nearby nodes are determined based on the information stored in a KRM. The node degree of a KRM can have at most z number of neighbor nodes. The KRM transforms into z-regular KRG by having the at most degree of node equal to 'z'.

A simple algorithm [14] is used to obtain the information about the neighboring nodes. The expression for the same is shown in equation [1].

j+((-1)m)2z) where m={j/2z} - Equation [1]

For any given value j, algorithm calculates all the neighboring node positions.

Figures 3.1(i), 3.1(ii) shows the KRM of 4 and 8 nodes respectively. Here the sink node is the root and occupy the 0th cell position, all the nodes follow the root node. In figure 5.5 (i), by the definition of KRM, the sink node is selected as the root node and the neighboring cells are grouped as (N0, N1) and (N0, N2). They are all the neighbors of each other. The same procedure is followed for higher number of nodes.

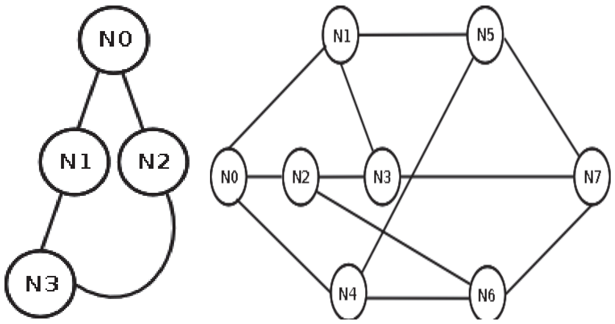
N0	N1
N2	N3

(i) KRM of 4 nodes

N0	N1	N3	N2
N4	N5	N7	N6

(ii) KRM of 8 nodes

Figure 3.1 KRM of sensor nodes



(i) KRG of 4 nodes (ii) KRG of 8 nodes

Figure 3.2 KRG of sensor nodes

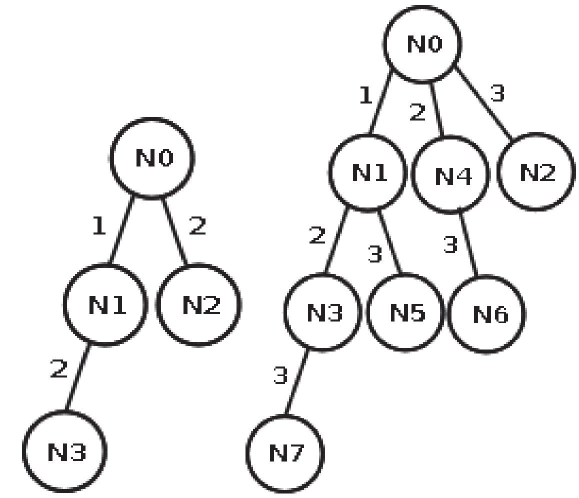
The Karnaugh graph is constructed as shown in figure 3.2 (i), (ii) and Table 3.1 and 3.2 shows the adjacency lists of 4 and 8 sensor nodes respectively. KRM can be computed for other topologies (i.e., M>>8).

Node	Adjacency Relationship
0	1 → 2 → NULL
1	0 → 3 → NULL
2	0 → 3 → NULL
3	1 → 2 → NULL

Table 5.1 Adjacency list of 4 nodes

Node	Adjacency Relationship
0	1 → 2 → 4 → NULL
1	0 → 3 → 6 → NULL
2	0 → 3 → 6 → NULL
3	1 → 2 → 7 → NULL
4	0 → 5 → 6 → NULL
5	1 → 4 → 7 → NULL
6	2 → 4 → 7 → NULL
7	3 → 5 → 6 → NULL

Table 5.2 Adjacency list of 8 nodes



(i) CATree of 4 nodes (ii) CATree of 8 nodes

Figure 3.3 CATree of sensor nodes

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The collision avoided tree from a KRG of M motes are formed and is called the Collision Avoidance Tree or CATree. It is a tree with the sink as the root node and it will gather all the sensed information from the successor nodes by avoiding both node and link level collision. Figure 3.3 (i) and (ii) shows the optimal congestion avoided CATree of four and eight motes. Here the motes are organized in a manner that the data flow through the network sequentially from the leaves which is free from congestion.

IV. SIMULATION AND RESULTS

MATLAB is used to simulate wireless sensor network. Three hierarchical levels for configuration are differentiated. The source code is based on Java. The analysis of simulated data is supported by a variety of built-in functions. A different graphical presentation for the simulation results exists.

A. Experimental Results

The main focus of the network simulation is to analyse network performance in the context of a WSN. MATLAB has been used to implement CATree of sensor nodes and to measure the performance of data retrieving strategy using a sink.

In all four test scenarios, sink and all other sensor nodes are stationary. Nodes N = 50 are uniformly deployed throughout the grid of medium 100 x 100 scale. In the first scenario network is a Star topology. A proper sink placement is examined so that each node will be at 1-hop distance and can send data directly using AODV protocol. In the second scenario, network is a Mesh topology and the static sink or the ZigBee coordinator is surrounded by a group of ZigBee routers and end devices. The fourth test scenario is a CATree network. Other parameters used in simulation are:

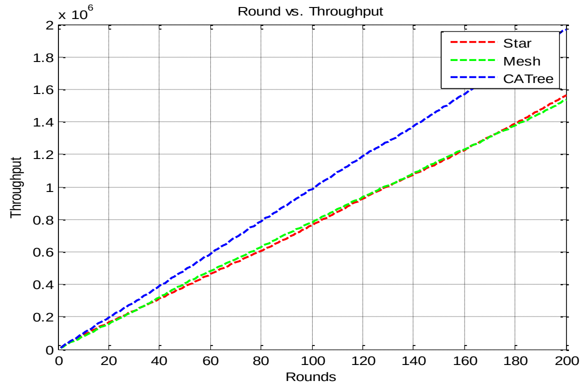
- sensor node distribution: uniform
- receiver sensitivity: -90 dbm
- packet size: 1024 bytes
- packet generation interval: 0.5 sec
- data rate: 250 kbps
- no of nodes: 50
- grid size: 100 x 100

Performance evaluation of four test scenarios is conducted on the following metrics captured from MATLAB statistics:

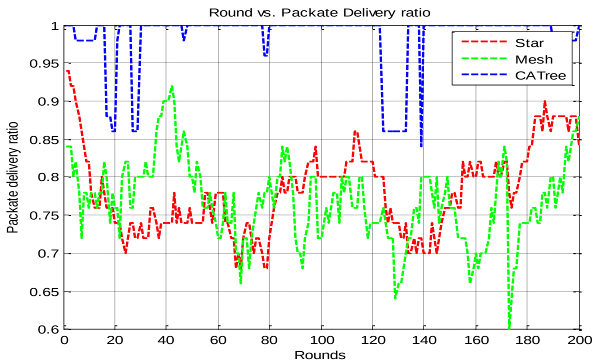
- Throughput
- Packet Delivery Ratio
- Energy Dissipation

B. Evaluation and Discussion

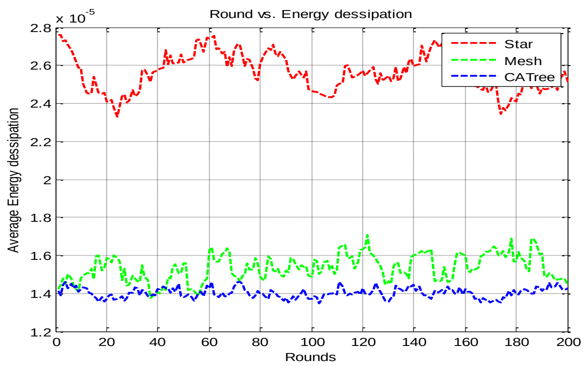
Figures 4(a), 4(b), 4(c) below show that CATree Topology outperforms star and mesh network with a static sink in network throughput, packet delivery ratio and energy dissipation. Moreover, significant improvement has been achieved in energy dissipation and the packet delivery ratio. Congestion free routing ensures two packets cannot reach a point in the network at the same time and avoid packet collision. Packets are not dropped by the network. As a result, packet retransmissions are reduced and packet delivery ratio improves. Hence in all aspects CATree can be thought off to use in order to maximize WSN lifetime.



4(a) Throughput



4(b) Packet Delivery Ratio



4(c) Energy Dissipation

V. CONCLUSION AND FUTURE WORK

The suggested mechanism in this paper achieves making the sensor node to consume less energy. In the proposed system, three topological types are considered which includes star topology, mesh topology and CAtree topology. The star topology provides a direct pathway between the nodes and the base station. The mesh topology form clusters and communicates to the base

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Vol. 5, Issue 7, July 2016

station through a cluster head. The CAtree topology provides multiple hops for each node. It is observed that CATree topology is efficient compared to other two topology with respect to network throughput, packet delivery ratio and energy dissipation.

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