Use of addressing mechanism in cluster based Wireless Sensor Network protocol for performance enhancement

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Abstract— The study of wireless sensor networks is such a challenging task as it is necessary to gain lots of knowledge from various disciplines. Wireless sensor network is characterized by its small size that contains sensors, transceiver, power supply, battery, microcontroller and memory. Routing algorithms, addressing mechanisms, proper balance between communication, signal processing and data processing capabilities must be found to fulfill the requirements for low device complexity together with low energy consumption. These areas motivate a huge effort in research activities. In order to efficiently construct a WSN consisting of many sensor nodes, it is necessary to apply some addressing mechanisms. When low cost small area network is required, ZigBee wireless sensor network can be used. ZigBee is an IEEE 802.15.4 wireless communication standard which specifies some addressing mechanisms. Some addressing mechanisms are distributed address assignment mechanism (DAAM), stochastic addressing assignment mechanism (SAAM), long thin wireless sensor network (LT-WSN) and distributed borrowing address assignment (DIBA). In this thesis I propose to incorporate any one clustering algorithm of wireless sensor network with an addressing mechanism proposed in ZigBee standard to enhance the performance. Performance of the sensor network will be evaluated in two cases, with implementing ZigBee addressing mechanism in our clustered wireless sensor network and without using it.

Keywords— ZigBee, Addressing, DIBA, Wireless Sensor Network.

I. INTRODUCTION

A Wireless Sensor Network (WSN) consists of spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure, etc. Addressing plays vital role in traditional IP based networks. An IP address is globally unique and is assigned to each node. IP addresses should be unique so that node can be identified uniquely. In wireless sensor networks, each sensor in the network is given an address for unique identification. Different addressing mechanisms available in wireless sensor networks can be categorized as ‘Stateful’ and ‘stateless’. [1] Stateful approach makes use of an address allocation table. ‘Stateless’ approach does not use allocation tables. When new node enters in the network then it will be assigned with some address therefore it can be identified uniquely in the network. Some addressing mechanisms don’t assign the address uniquely while some mechanisms do not guarantees the maximum utilization of available addresses.

Type of wireless sensor network depends upon the application. When low cost small area network is required, ZigBee wireless sensor network [2] can be used. ZigBee is an IEEE 802.15.4 wireless communication standard. It is used to build low power consumption and low cost network. It is also called a representative protocol for wireless sensor network. IEEE 802.15.4 defines lower layers of protocol stack which are MAC and PHY. IEEE 802.15.4 standard gives the advantage of a powerful physical radio. It also consist logical network, security and application software in its architecture. ZigBee can be implemented in star networks, peer-to-peer networks, mesh networks and cluster-tree networks. ZigBee services include personal health care, telecom services, pc and peripherals, lighting control, access control and so many more. ZigBee/IEEE 802.15.4 wireless sensor network presents different addressing mechanisms. In this paper we have describe four different addressing schemes which are: Stochastic Address Assignment Mechanism (SAAM), Distributed Address Assignment Mechanism (DAAM) [3], Long Thin Wireless Network [4] address assignment scheme and Distributed Borrowing Addressing Scheme.

This paper is organized section wise as follows. In this paper, section II describes the introduction of ZigBee wireless standard and the addressing mechanisms SAAM, DAAM, long thin wireless network and distributed borrowing addressing scheme. Section III describes the experiment of the incorporation of wireless sensor network with DSDV protocol and DIBA addressing mechanism. DIBA addressing mechanism is used in WSN without clustering and with clustering. Finally, section IV describes conclusion summarizing the study.
II. THE OVERVIEW OF ZIGBEE NETWORK LAYER

The ZigBee IEEE 802.15.4 covers the physical layer and the MAC layer of low-rate WPAN. IEEE Standard 802.15.4 defines the physical layer and medium access control sublayer specifications. It has low-data-rate wireless connectivity. It supports fixed, portable and moving devices. ZigBee used where very limited battery consumption is required. The IEEE 802.15.4 standard defines the device types that can be used in a LR-WPAN which are Full Functional Device and Reduced Functional Device. [5] Three different types of data transfer exist in ZigBee network. Data transfer from a device to the PAN coordinator, data transfer from the PAN, Peer-to-peer data transfer. Figure 1 shows the ZigBee stack with its layers.

**Figure-1: ZigBee stack**

A. Devices in the network layer:

ZigBee coordinator (ZC): Responsibility of ZC is to take care of initializing, maintaining, and controlling the network.

ZigBee router (ZR): ZigBee router belongs to the network backbone which is useful for routing a node.

ZigBee end device (ZED): ZED is used in a tree network. The coordinator and routers can announce beacons in the network.

ZC, ZR and ZED are very essential devices in ZigBee wireless sensor network. Each of them handles their assigned task to synchronize the operation in network. Lm, Cm and Rm are topological parameters for a ZigBee Tree. Lm is the maximum depth value of the tree. In the figure 1, the maximum depth of the tree is 3 which is Lm. Cm is the maximum number of children of a ZC/ZR. Rm is the maximum number of children of a ZC/ZR that can be route. The head node is considered as ZC. The nodes at the Lm are always ZEDs, which can be shown in the below figure 2.

**Figure-2: ZigBee tree structure**

B. Security in ZigBee 802.15.

The algorithm that is used for encryption in ZigBee network is the Advance Encryption Standard. It provides a security baseline including the ability to maintain an ACL and use symmetric cryptography for data encryption. The higher level layers decide when security is needed and the upper layers are responsible for device authentication and key management. The security mechanism covers the network and the application layer. End-to-end security is also supported in ZigBee where the source and destination devices have access and use the same share key.

**Contribution and assumptions**

It is impossible to develop a global addressing mechanism for the deployment of big number of sensor nodes. Classical IP based protocols are useless for the wireless sensor networks. However, there are so many addressing mechanisms derived for wireless sensor networks. ZigBee is IEEE 802.15.4 wireless communication standard when low power and low cost is required. There are different addressing mechanisms proposed for ZigBee standard. Our assumption is to incorporate any one clustering algorithm of wireless sensor network with the addressing mechanism proposed in ZigBee standard. Performance of the sensor...
network will be evaluated in two cases, with implementing ZigBee addressing mechanism in our clustered wireless sensor network and without using it.

C. Stochastic Address Assignment Mechanism (SAAM)

Stochastic Address Assignment Mechanism (SAAM) Proposed in ZigBee in 2007. It checks whether or not addresses are duplicate after assigning random addresses to the nodes. On-demand [6]-[7] protocol or table-driven protocol [8] is used for routing when packets are transmitted in the network, at the time of transmission addresses are assigned in random order. Addressing is not hierarchical in the network. Address conflicts occur when two or more devices select an identical network address. Some device may conflict therefore they need to rejoin the network. Thus, conflicting devices will get a new address. Tree-based routing is no longer feasible with SAAM. These routing protocols are inappropriate for low power and low capacity wireless sensor networks because they require frequent broadcasts and large packet header size. It also demands high memory.

- Address assignment mechanism in SAAM

  The AODV routing protocol is used in the SAAM. It routes packets in the sensor network. the address conflict resolution may occur and therefore it takes more time to establish the network. Power capacity is also limited in sensor network. Thus, speed of the network is less than wired network commonly used with AODV. SAAM and AODV routing are not efficient ideas for sensor networks.

D. Distributed Address Assignment Mechanism (DAAM)

DAAM organizes all the nodes in tree networks and routes packets using address information without requests for extra routing tables. It also doesn’t need route retrieval processes and still it guarantees the uniqueness of addresses with a regular address assignment technique.

The aim of DAAM is to make a self-organizing [9] wireless sensor network. It is difficult to expand the network area in a scalable manner using DAAM. When any node wants to enter in the network then newly entering node N requests address assignment to parent node P. parent node P can assign the address to the newly entering node N by the equation 1.1. In centralized methods all nodes are managed by central node. Linear addressing assignment requires an additional table for routing. It also needs messages for route setup and an additional header format. It fails to maintain the advantage of DAAM and centralized addressing also takes too much delay before address assignment because they have to communicate with central node. The delay may cause timeout of the association process and address assignment may be fail. The addressing mechanism should be such that it achieves a higher address assignment success rate and it also guarantees the uniqueness of addresses. Therefore different addressing assignment mechanisms should be tested for comparison and use them according to respective application.

![Figure-3: Address configuration in DAAM](image)

- Working of DAAM

  In DAAM, a parent node utilizes Cm, Rm, and Lm to compute a Cskip function. Cskip is used to compute the size of its children’s address pools. Maximum tree depth is denoted by Lm, the maximum number of children is Cm and the maximum numbers of children that can be route are Rm.

\[
C_{skip} = \begin{cases} 
1 + C_m \times (L_m - d - 1) & \text{if } R_m = 1 \quad \text{(a)} \\
1 + C_m - R_m \times C_m \times (L_m - d - 1)/1 - R_m & \text{or (b)}
\end{cases}
\]

Equation 1.1

Cskip(d) is the depth value of parent. Suppose parent node which is currently at depth “d” has an address “Ap”. And nth child router is assigned to following address:

\[
A_p + (n - 1) \times C_{skip}(d) + 1
\]

And nth child end device is assigned to following address:

\[
A_p + R_m \times C_{skip}(d) + n
\]

- Properties of DAAM

  Locations in the same sub tree are allocated a continuous address block. It uses hierarchical addressing and the addresses of each device are assigned by its parent. Here it reserves an address for each possible location in the tree. Routing is done without using a routing table.

- Weakness of DAAM

  It fails in providing flexibility. The highest address can be used in this mechanism is: Cskip(0) × Rm + Cm − Rm. Addresses higher than this cannot be used.

Depending on the network size and network structure, both SAAM and DAAM addressing schemes have their advantages and disadvantages. Especially the network structure can be analyzed by the addressing scheme, since the network depth can be limited.
E. Long Thin WSN addressing scheme

Wireless sensor network applications differ in many areas and Long-Thin Network is used in many applications. Long-Thin Network is one the topologies. Some of the applications of LTN are in surveillance, leakage detection, flood protection, vibration detection, monitoring tunnels, street lights monitoring, pedestrian detection and so many other.

ZigBee propose a new addressing mechanism which is easy to use in long thin wireless sensor network. Goal of this addressing scheme is to automatically form a long thin WSN, give addresses to nodes and conduct routing process. Proposed long linear network topology is called Long Thin Wireless Sensor Network (LT-WSN) which is based on ZigBee. All nodes in LT-WSN are divided into clusters. Each cluster contains one head and a bridge. All other nodes are in-between head and bridge of the cluster.

D. Distributed Borrowing Addressing Scheme

Distributed borrowing addressing scheme is the advance mechanism than SAAM and DAAM. It preserves the advantage of DAAM and also provides scalability in it. The working of distributed addressing mechanism is explained in this context. If a new node enters in a ZigBee network then it should find candidate nodes for its parent. Distributed borrowing addressing scheme can be explained in figure 5. If the new node enters in a network and if it is in the radio coverage of parent node p, new node can be assign address by its parent by analyzing the unoccupied child addresses available. Routers take care of the beacon frames to be broadcast. These beacon frames consists the number of children that they can add which are the number of remaining addresses which can be assigned. And these addresses are called as available address count. When available addresses remaining, parent node will assign if it gets association request by any node. If the available address count is zero or the tree depth is Lm or more then the new node gets the address by “address borrowing” scheme.

- If parent node p receives an association request from newly entering node N and if parent node has a limit of 3 children, an address for node N cannot be assigned because node p already has nodes a, b, and c as children therefore node p should broadcast an address borrowing request (AB_REQ) messages to borrow addresses from its parent node and children which are called neighbor nodes. The neighbor nodes h, a, b, and c respond to node p with address borrowing response (AB_RSP). This message includes Available Address and Available Address Count. If AAC is zero then AB_RSP message will not be transmitted.

- The selection procedure for borrowing address is done by following steps. First of all an AA of the node with the biggest AAC is selected and if the AACs are identical then an AA of the neighbor node with the highest address will be selected. This is a method of borrowing unused addresses from neighbor nodes and adopting them. This mechanism solves the problem that addresses cannot be assigned to nodes newly entering a network due to tree depth and limits on the number of children in the case of DAAM. Different simulation tools can be used for simulation. Uniform node placement and random node placement can be performed by the tool.

- The working of distributed borrowing addressing mechanism is explained in the above context. According to the IEEE 802.15.4 standard, a device sends the data request command for the association response message to the coordinator macResponseWaitTime symbols after the acknowledgment of an association request command. The maximum value of macResponseWaitTime symbol is 64x BaseSuperframeDuration, which is 983 ms at the 2.45 GHz band. Time taken to exchange AB_REQ and AB_RSP messages is the delay between an association request command and an association response command. MacAckWaitDuration is the maximum number of symbols to wait for an acknowledgment frame to a transmitted data frame. The data rate of the IEEE 802.15.4 standard is 250 kbps at the 2.45 GHz.

![Figure-4: Long thin wireless sensor network](image-url)
III. Results:

In our dissertation, we have calculated 4 Quality of Service parameters of wireless sensor network which are end to end delay, throughput, utilized energy and packet delivery ratio. Graphs for all these parameters are shown in the following explanation.

Simulation environment and platform:

- Simulator - Ns-2
- Channel type - Wireless channel
- Simulation time - 10 seconds
- Simulation area - 500 m X 500 m
- Max packet in ifq - 200
- Routing protocol - DSDV
- Traffic type - CBR(TCP)
- Mac type - Mac/ZIGBEE
- Movement trace - Off
- No. of Nodes - 50

The performance of wireless sensor network can be evaluated using its QoS (Quality of service) parameters. Performance of wireless sensor network using DIBA addressing mechanism can be evaluated by comparing it with another wireless sensor network with same configuration that is without DIBA addressing mechanism.

Figure 5. Working mechanism of DIBA
As shown in figure 6, packet delivery ratio is also compared with other network. We can show that PDR is higher after some amount of time when using DIBA mechanism. Hence, it will be used in such applications where more packet delivery ratio requires. Packet delivery ratio will always high when using cluster based wireless sensor network with ZigBee addressing mechanism.

We can show in figure 7 that throughput will drastically decrease than the general network, it means it’s not preferable to use when higher throughput is required. Even if we use it in cluster based wireless sensor network then also the throughput will be less.

Average end to end delay is high when using DIBA for higher values and more time as shown in figure 8. Therefore it can be useful for small operation of network. But the cluster based wireless sensor network utilizes less time and the delay will always be lesser than other network for any simulation time.

We can also show in figure 9 that energy consumption is less for DIBA network as compare to DSDV network. Therefore, it can be used where energy saving is main criteria so network lifetime can be increased. When using cluster based wireless sensor network, energy will be utilized more which can be useful in energy sensitive network.
Various implementation parameters are calculated from generated trace file. In this thesis, we have calculated throughput, energy utilization, average end to end delay and packet delivery ratio. These parameters can decide the quality of network. Performance of the sensor network can be increased if one of this parameter gets better value. But in real system, it’s not possible to increase the values of all parameters at same time because various parameters may affect each other.

Time and energy are such two parameters which always affect each other. We can say that they are in inverse proposing to each other. We can also see that in our experiment. Whenever we have used DIBA addressing mechanism in our WSN, it utilizes more energy but on other hand it causes more delay in the network.

We can also analyze from the graph that packet delivery ratio is also higher in DIBA sensor network as compare to general sensor network. Hence, we can say that packet delivery ratio is in co-relation with end to end delay. If the average delay of the network is more, it means it gets more time for communication and therefore destination will receive maximum number of packets from the source.

Future enhancement

In future, we can use another ZigBee addressing mechanism in our experiment to increase the performance of throughput and relate it to this experiment result. If we get the improvement then we can use it in future for wireless sensor networks so that such application which needs higher throughput can use this method. We can also calculate some other quality of service parameters for wireless sensor network such as sensing time of sensor, temperature generated from nodes, lifetime of network, etc.

IV. Conclusion

The performance of DIBA addressing mechanism can be compared with the DSDV protocol in wireless sensor network. As per our experiment, we have conclude that when DIBA addressing mechanism of ZigBee 802.15.4 is used in wireless sensor network, it will give better performance in case of end to end delay, energy utilization of nodes and packet delivery ratio. But the drawback is very less throughput. Hence, such addressing mechanism is used in wireless sensor network in time sensitive application or when low energy utilization is required.

REFERENCES


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