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Address Borrowing In Wireless Personal Area Network

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***Abstract*—IEEE 802.15.4-2003 is a standard for Low rate, Low powered, Low memory wireless personal area network (WPAN).The Physical layer (PHY) and Medium access control (MAC) specification has been given by IEEE [12, 11]and the Network layer by ZigBee Alliance[17]. They support two kind of net work Tree/Mess. In tree network no routing table is required for routing. After the great success in PAN this technique has also been tried to apply in business Network too. The main problem with this routing is that the maximum length of the net work is 16 hops and in some cases the network can not grow because of the exhaustion of address in some part while the other part is very poorly loaded. Here In this paper we have provided a unified address borrowing scheme which can be easily applied to grow the network beyond 16 hops and overcome the address exhaustion problem by borrowing address.**

Index Terms—PAN;WPAN;Tree; Mesh; Address Borrowing; Routing

I. Introduction

Wireless **P**ersonal **A**rea **N**etworks (WPANs) are used to convey information over relatively short distances. Unlike wireless local area networks (WLANs), connections effected via WPANs involve little or no infrastructure. This feature allows small, short-range operation, reliable data transfer, and a reasonable battery life, power-efficient, inexpensive solutions to be implemented for a wide range of devices.

Two topologies are used in this kind of network Tree and Mesh. The beauty of tree address allocation is that it does not require any routing table to forward a message. It uses a simple mathematical equation for address assignment and routing.

II. Overview of Tree Routing

There are different kinds of routing, Distance vector Routing [1, 10, 16], Compact Routing etc. but tree routing is simplest among them as it does not require any Routing table. The type of network topology in which a central 'root' node (the top level of the hierarchy) is connected to one or more other nodes that are one level lower in the hierarchy (i.e., the second level) with a point-to-point link between each of the second level nodes and the top level central 'root' node, while each of the second level nodes that are connected to the top level central 'root' node will also have one or more other nodes that are one level lower in the hierarchy (i.e., the third level) connected to it, also with a point-to-point link, the top level central 'root' node being the only node that has no other node above it in the hierarchy – the hierarchy of the tree is symmetrical[2], each node in the network having a specific fixed number, f, of nodes connected to it at the next lower level in the hierarchy, the number, f, being referred to as the 'branching factor' of the hierarchical tree.

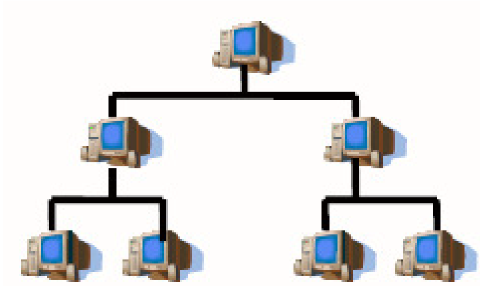

Figure 1: Tree Network

A. Distrubuted address assignment

Given values for the maximum number of children a parent may have, *nwkMaxChildren* (C_m), the maximum depth in the network, *nwkMaxDepth* (L_m), and the maximum number of routers a parent may have as children, *nwkMaxRouters* (R_m), then $C_{skip}(d)$, essentially the size of the address sub-block being distributed by each parent at that depth to its router-capable child devices for a given network depth, d, is:

$$C_{skip}(d) = \begin{cases} 1 + C_m.(L_m - d - 1), If R_m = 1 \\ \dfrac{1 + C_m - R_m - C_m.R_m^{\,L_m - d - 1}}{1 - R_m}, Otherwise \end{cases}$$

Network addresses to the end devices are assigned using the following equation [17].

$$A_n = A_{Parent} + C_{skip}(D).R_m + n$$

$$1 \le n \le Cm - Rm \ And \ A_{parent} \ is \ address \ of \ parent$$

B. *Network formation*

Let Cm=2, Lm=4, Rm=2

Depth in the Network	OffestValue [Cskip(d)]
0	15
1	7
2	3
3	1
4	0

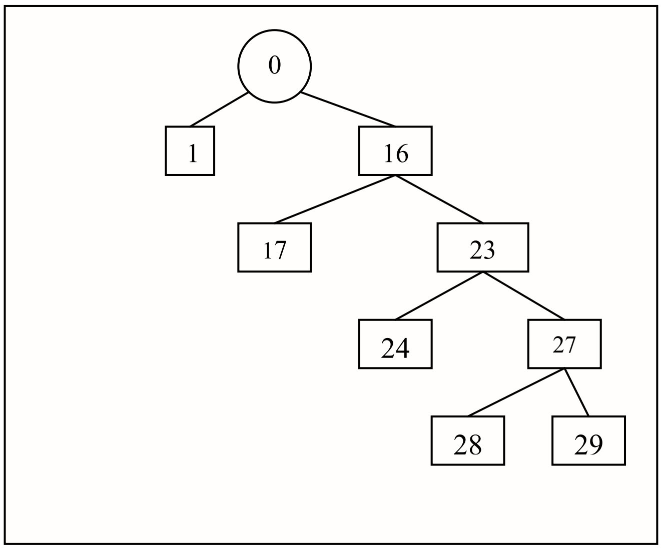

Figure 2: Address Allocation

C. *Advantage*

Simplicity-It's a very simple network no complex path is formed. A device only communicates with its Parent and Childs.

Scalability – The tree network can grow more than that of mesh networks.

D. *Disadvantage*

The address is 16 bit so the maximum length of the network is 16, and available address at a node can not be used in other nodes.

Now in Figure 2 the Cskip (d) for node 28 and 29 is 0 that is no address is available at these nodes, so if any node wants to join the network at either of these two nodes will fail even though free address is available at other node. The proposed algorithm discussed next section suggests a way to overcome this.

III. PROPOSED ADDRESS BORROWING SCHEME

In this scheme a node will be allowed to join a network at a node even if it has exhausted its available address by borrowing a address from a different node which is having free address and assigning it to the requesting node .i.e. the new node will physically be attached to some node and will have the physical address of some other node with addition of very small routing table.

In the following Figure 3 Node 25 is physically attached to node 28 but the address **'25'** has been borrowed from node 24. The dotted line indicates that relation ship.

A. *Design consideration:*

1. PAN devices are very low powered device i.e. they require very lesser amount of power to drive
2. PAN devices have very lesser amount of memory typically several Bytes to a few KB.

B. *Required Data Structure*

Probable address available table**:** This table will be maintained at the PAN coordinator i.e. Node 0 in **Figure 3**. It will have 3 column Router address, Child Router free and Child end device free.

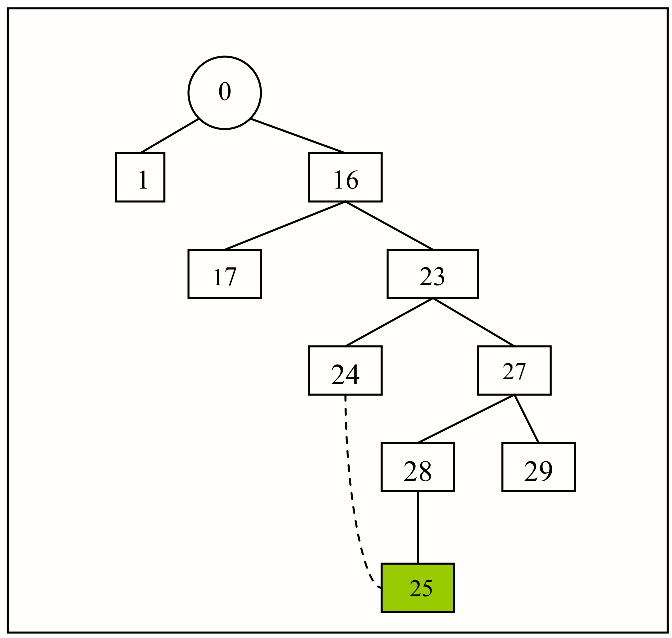

Figure 3: Address Borrowing

Router Address	**Child Router free**	**Child end device free**
1	P	F
17	E	E
27	F	F
24	T	F

Router address is the address of the Node where free address might be available.

Child Router address free and child end device free column will indicate the availability of the address it can have 4 values E=Empty P=Partially Full and F=Full T= Threshold Reached.

Initially these two columns will be marked as E for all the Routers, and will be updated by the PAN coordinator as Network grows using the algorithm discussed later.

Visiting child table: This table will be maintained at the Node which has borrowed the address from other node i.e. Node 28 in Figure 3. For most of the node this table will be empty.

Actual Address	Parent Address
25	24

This table will be storing the actual address of the visiting node.

Tunnel table: This table will be maintained at the node which has given the address i.e. Node 24 in **Figure 3.** This table will be used to tunnel the packet to the intended receiver. This table will have two columns one for Actual address and the other for tunnel address.

Actual Address	Tunnel Address
25	28

This table will be empty for most of the nodes.

C. Messages and their Descriptions

Following messages will be used in order to borrow a free address from any node. The address can be a single end device address or a full address block (router address).

getFreeAdd:

Description-This message will be send to get free address.
Sender - Any node which has exhausted its address.
Receiver- PAN coordinator.
Parameters: Router/End device address required.

hasFreeAdd:

Description- It will be sent to query the availability of free address at any node.
Sender - PAN coordinator.
Receiver- Any node selected by Pan Coordinator using Chose Probable node algorithm.
Parameters: Router/End device address required.

replyHasFreeAdd:

Description-It will be send in reply to hasFreeAdd.
Sender - Any node which has received hasFreeAdd.
Receiver- PAN coordinator.
Parameters: No of available address, donated address, Address range (Cskip (d)) in case of router address

replyGetFreeAdd:

Description- This message will be sent to inform the available address.
Sender – PAN Coordinator.
Receiver- Address requesting node.
Parameters: Free Address, Donor Address, Address range (C_{skip}(d)) in case of router address.

deallocateVisitingAddress:

Description- This will be send when the visiting node wants to disconnect from the network.
Sender - Parent of the visiting node.
Receiver- Address donor whose address has been fetched from visiting child table.
Parameters: Actual address.

emptyChild:

Description- This message will be send when any node become empty i.e. have no child.
Sender Any node.
Receiver- PAN coordinator.
Parameters: End device free/router free

addressFull:

Description- This message will be send when a node has exhausted all its available address.
Sender - Any node which has exhausted its address.
Receiver- PAN coordinator.
Parameters: Router/end device address full

D. Method descriptions

hasFreeAdd: This method will be invoked by any node after receiving **joinNetwork** message from a node. If the node has exhausted its available address it will send **getFreeAdd** message to the PAN coordinator.

choseProbableNode: This method will be invoked by the PAN coordinator after receiving **getFreeAddress** message from any node. It will look in the **Probable Address Available Table (PAAT)**[§] and select a probable node which can donate address based on the following logic [Figure 4].

In Figure 3 the address is available at node 1, 17 and 24 as the node 24 is closest to node 24 the algorithm will select it for the 1st time.

If some node say node 29 wants to send a message to node 25 the message will traverse in the following way.

29→27→23→24(Tunnel the packet to 28)→23→27→28 (Route to visiting child) →25

[§] Here the algorithm will look for the nearest node to the address requesting node so that message transmission overhead due to tunneling can be minimized.

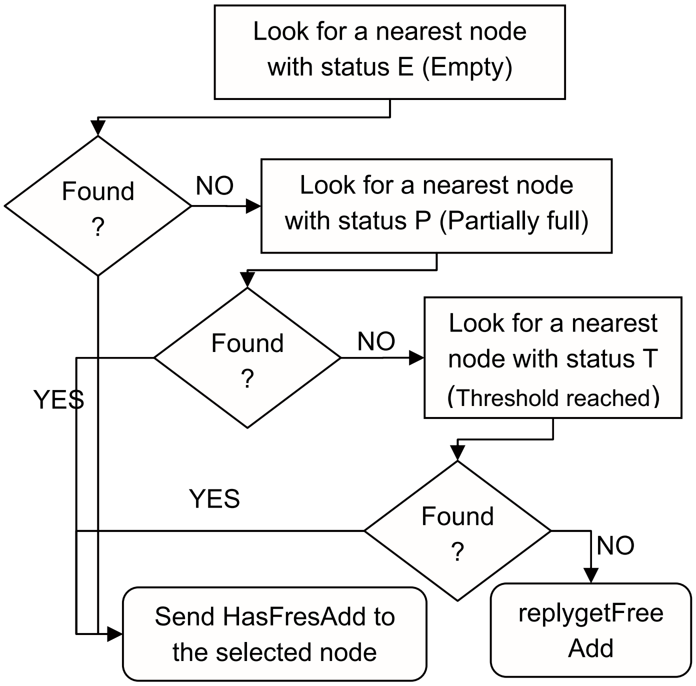

Figure 4: Probable Node Selection

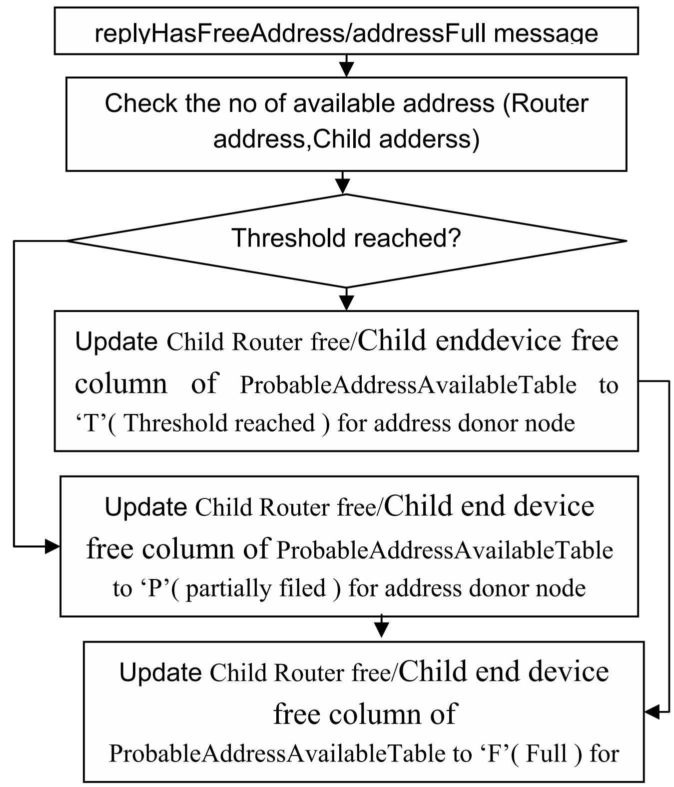

Figure 5: Probable Address Table Update

This scheme will be use full for highly communicating network i.e. where every participating node used to communicate with each other but if the devices are less communicating i.e. they rarely send messages but require a fast response when they want to join the net work then a slide variation of the algorithm can be used where PAN coordinator will chose the node which is closest to itself and thus minimal delay will be incurred. So in that case PAN coordinator will select **Node 1** as the probable node.

UpdateTunnelTable: This method will insert a new row in the Tunnel table containing the address of the node to which it is donating the address and the address itself. This information will be used to tunnel the packet to the actual recipient.

Update ProbableAddressAvailableTable: This method will be invoked by the Pan coordinator to update **ProbableAddressAvailableTable** after receiving **replyHasFreeAddress message** from address donor node or **addressFull message** from any node to reflect its updated knowledge about the free address available node.

Update Visiting Table: This method will be invoked by the address requesting node after receiving **replyGetFreeAddress** message from PAN Coordinator to update the Visiting child table to insert the visiting child and address donor address into Visiting child table

E. Message Passing Overhead Calculation

Two message are required to join a network by any node one for join request and the other for acceptance. Four additional messages are required for borrowing address from other node

let M= No of Node, X% is the percentage of address borrowing required to form the net work average Distance (No of hops) between PAN coordinator and address Borrower be P, Between PAN Coordinator and Donor be Q and Donor and Borrower be R, the depth of the network be S, Total no of message sent is T, and U% be the percentage of tunnel message. Figure 6 presents the address borrowing message sequence, Figure 7 present packet routing sequence and Figure 8 represents Leaving the Network message sequence.

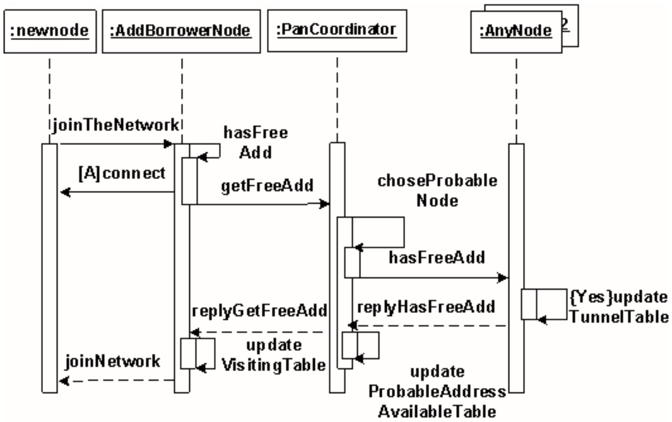

Figure 6: Address Borrowing Sequence

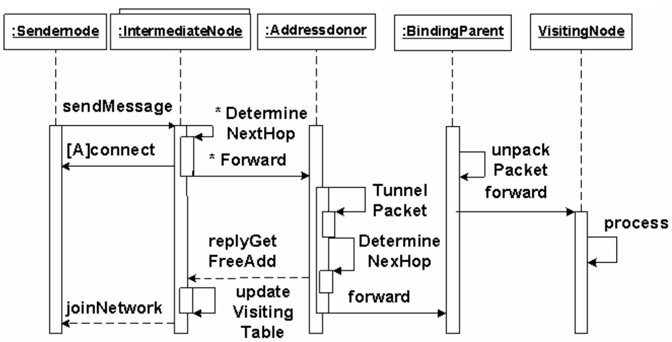

Figure 7: Packet Routing Sequence

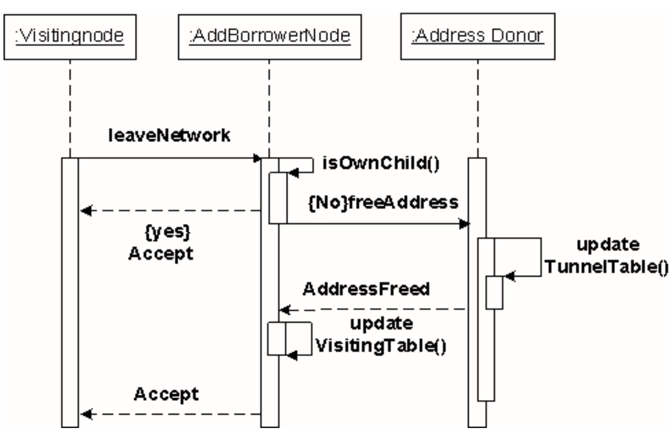

Figure 8: Leave Network Sequence

Total message (TM) for network creation without borrowing (WOB) =2*M

The Average distance (AV) traversed per data message (WOB) is S.

Total message for network creation with borrowing (WB) = 2*M (1+ 2*X/100)

Average message per Node is 2*(1+2*X/100)

The Average distance traversed per data message for address borrowing is S (1+ (U*R/100))

Now let's see the performance of the algorithm for different network configuration. As address borrowing will only take place when a node has exhausted its available address, the percentage of borrowing will be lower, the no of tunneled message will also be very less compared to the total no of message sent over the network as the 1st message from a sender to a visiting node only require tunneling the subsequent message will be send directly to the visiting node.

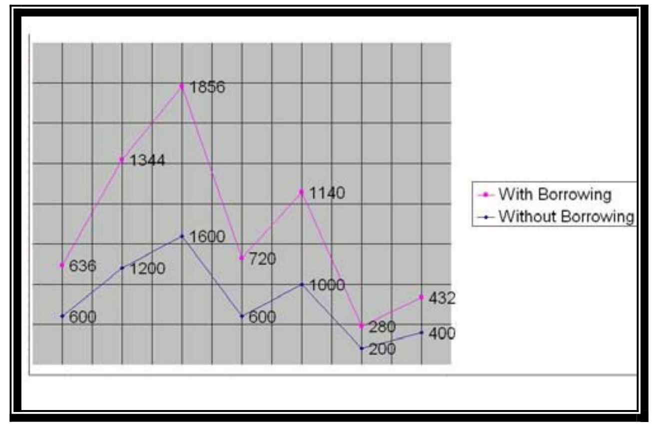

Figure9:Total No of message for Network Creation Graph

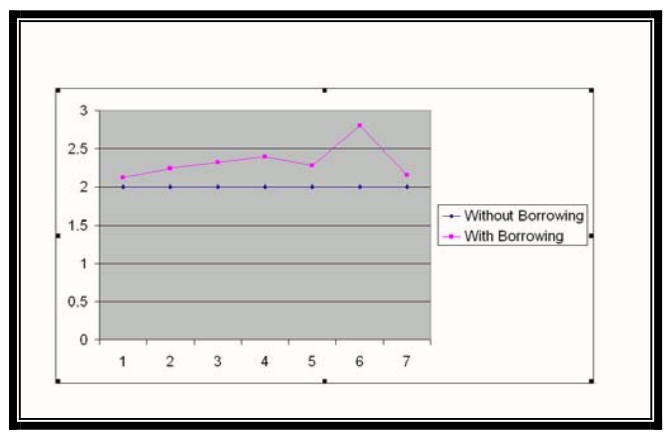

Figure 10: Average No of message for Network Creation

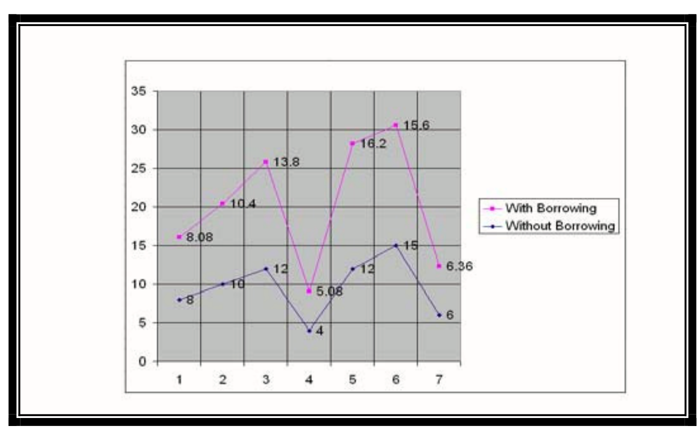

Figure 11: Average Distance Traversed by each message

Parameters ↓	Total message for network creation		Average no of message to join the network per Node		Average distance traversed by each data message	
	WOB	WB	WOB	WB	WOB	WB
M=300 X=3% S=8 U=.5% R=2	600	636	2	2.12	8	8.08
M=600 X=6% S=10 U=1% R=4	1200	1344	2	2.24	10	10.4

IV. RELATED WORK

Wireless networks have rapidly gained popularity since their introduction in 1970s. However, an investigation into low-cost, low-rate, low-power PAN is relatively new. In [7] authors explored the complex behavior of a large number of small low-power sensor nodes. Energy aware operation of wireless devices is the dominant theme in [13], [15].

Routing in wireless networks has been a fascinating topic of research for long. These routing protocols have to deal with the challenges of wireless networks, namely low-bandwidth, high error-rates and often energy and memory constraints. These algorithms are either table-driven (e.g. DSDV [5], WRP [Shree_Murthy]) or source-initiated, that is demand-driven (e.g. DSR, AODV [4, 6, 3])

A comprehensive survey of these protocols has been done in [9].

There is relatively scant literature on 802.15.4/ZigBee although its applications have been discussed in [14], [8]. Authors provide one of the first studies of the MAC sub layer while the recent paper [14] is a comprehensive performance evaluation of 802.15.4.

V. CONCLUSION

In this paper we have provided a unified address borrowing scheme which can be used to use WPAN in Business networks such as wireless sensor network in Mine by allowing the network to grow more than 16 hop using address borrowing scheme with marginal difference in performance in asymmetric tree configuration where a portion of the network is over crowded where the other part is very thinly loaded with plenty of free available address.

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