Single Level Address Reorganization In Wireless Personal Area Network

Debabrato Giri and Uttam Kumar Roy

***Abstract*—The Standard for Wireless personal area network(WPAN) has been given by IEEE 802.15.4-2003 these networks are consists of Low rate, Low powered, Low memory devices. ZigBee Alliance has provided Network layer specification and Physical layer (PHY) and Medium access control (MAC) specification has been given by IEEE. We have addressed the network depth problem in our paper "Address Borrowing in Wireless Personal Area Network" [8]. Now in some other network configuration the network may need to grow beyond the maximum breadth because of the asymmetric nature of the physical area. Here In this paper we have provided a unified address reorganizing scheme which can be easily applied to asymmetric tree network**

Index Terms—PAN; Mesh; Address Reorganizing; Routing; WPAN;Tree.

I. Introduction

WIRELESS **P**ersonal **A**rea **N**etworks (WPANs) are used to communicate information over relatively short distances. WPAN require relatively less or no infrastructure.

Tree routing is simplest as it does not require any Routing table. In tree network topology a central 'root' node is connected to one or more other nodes that are one level lower.

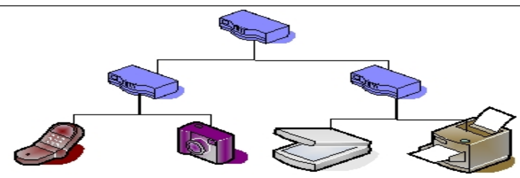

Figure 1: Tree Network

A. *Distrubuted address assignment*

For a 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 *[9]* by each parent at that depth d, is:

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

R^{th} Router address at depth D is:

$$A_{R^{th}} = A_{parent} + C_{skip}(d).(R^{th} - 1) + 1 \quad (2)$$

Network addresses to the end devices are assigned using

$$A_n = A_{Parent} + C_{skip}(D).R_m + n \quad (3)$$

B. *Network formation*

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

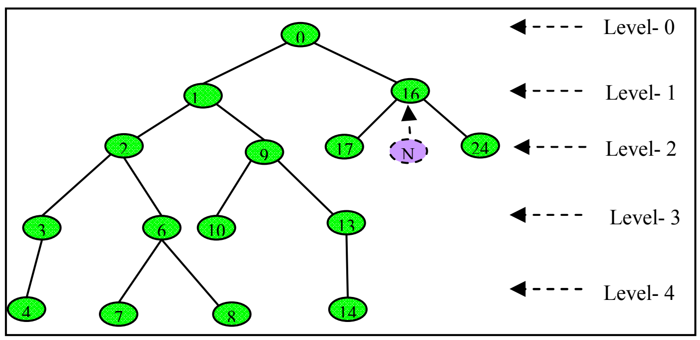

Figure 2: Address Allocation

C. *Tree/Hierarchical Routing*

For Router with address A depth d, if the following logical expression is true, then a destination device is a descendant:

$$A < D < A + C_{skip}(d-1) \quad (4)$$

If destination is a descendant of the receiving device, then it is checked if destination is a child end device using the equation

$$D > A + R_m.C_{skip}(d) \quad (5)$$

Dept. of Information Technology, Jadavpur University, Salt Lake Campus, Block-LB, Plot-8, sector-III, Kolkata-700098, India Email: debabrato.giri@tcs.com mail_debabrato@yahoo.com , u_roy@it.jusl.ac.in

978-81-8465-152-2/09/$26.00©2009 CODEC

If it is a child end device then the address N of the next hop device is given by: N=D. (6)

Otherwise, The next hop address is given by:

$$N = A + 1 + \left\lfloor \frac{D-(A+1)}{C_{skip}(d)} \right\rfloor \times C_{skip}(d) \quad (7)$$

D. Limitations of ZigBee tree routing

One major problem of tree routing is that it limits network depth, breadth and maximum no of child. For Cm=8 and Rm=4, the maximum possible depth Lm=7 only.

II. PROPOSED ADDRESS REORGANIZING SCHEME

In this scheme a node will be allowed to join a network at a node even if it has reached maximum no child by Address reorganization. This scheme can be used in part of the network where the network wants to grow in breadth rather than in depth i.e. we are expecting that the depth will be less than Lm at that part of the network because of asymmetric physical structure.

In Figure 2 the maximum length of the path from root which goes via Node 16 is two i.e. the depth of the network at that part is 2(less than Lm) which suggests that at that part of the network the growth is around the breadth and not in depth . We can apply our algorithm at that part i.e. the part where the maximum depth is not required but the width is required more than the maximum.

A. Advantages of Address Reorganization:

Simplicity-proposed address reorganization algorithm is very simple and no complex path is formed. Devices communicate with its Parent and Childs and next hop destination can be calculated using simple mathematical formula only.

Scalability – The tree network can grow more than that of mesh networks and the no of interconnection is less.

Can be applied in Asymmetric Network: In real world most of the networks area is asymmetric for example in a building the lower floors can have more rooms compared to upper floors and part of ground floor may have canteen/gym etc so does not require any network or a paddy field can have some irregular shape, proposed address reorganization technique is capable of handling all these and can be applied to all such asymmetric networks.

Flexible: In proposed address reorganization scheme any parent can increase its no of child device by reorganizing its address by any level so it is much more flexible.

Low over head: In proposed address reorganization scheme only the parent who has reorganized its address need to hold the transition table which has only four rows with two columns, no other node need to have any special data structure so the algorithm is having minimum overhead.

B. Overview of the Algorithm:

The Node which has reached its maximum child and wants to expand its breadth will use the next level Cskip value while distributing the address to its child i.e. if the node is at level K it will use the Cskip value for K+1, its immediate child will use K+2 and so on till Lm-1.By doing this the Node has gained one level of address which it can use for adding new child.

After address reorganizing the maximum no of child that can be added to that node will be Rm*Rm + Cm

For example if node 16 goes for address reorganization as it is at level 1 its original Cskip value is 7 but it will use its next level Cskip value i.e. level 2 which is 3, and the maximum no of child it can have will be 2*2+2=6 and the network depth at that part will be Lm-1=3.

So after address reorganization node 16 will be able to add 4 more children.

Following **figure3** shows the structure of the network after address reorganization

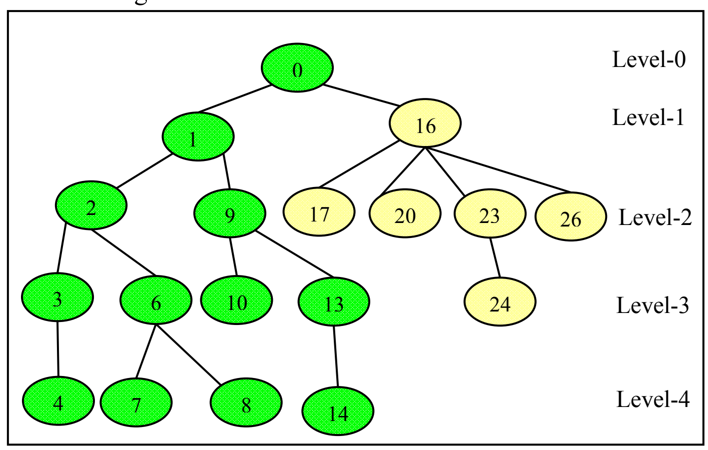

Figure 3: Address Reorganization

C. Required Data Structure

Transition table: This table will be maintained at the Node which has reorganized its address e.g. Node 16 in **Fig 3**. It will have 2 column Name and value.

Name	Value
Actual Cskip(Cskip)	7
Pseudo Cskip(Pcskip)	3
Actual Level(d)	1
Pseudo Level(Pd)	2

This table will have 4 rows and will be used by the address reorganizing Node while assigning address to its child devices.

In the above table Pseudo level(Pd)=d+1

and $P_{cskip}(d) = C_{skip}(d+1)$ (9)

978-81-8465-152-2/09/$26.00©2009 CODEC

All the child node of this will be at pseudo level Pd+1and there child at level Pd+2 and so on. That is the node which has re organized its address will physically be at level d but will virtually consider it to be at level d+1.

D. Static Single Level Address Reorganization

This type of address reorganization could be used in static networks where network structure is fixed and reorganization takes place at the time of network formation and it assumes that address given to a node is permanent.

Address Distribution:

At any Node if it has not reorganized its address or any of its parents have not reorganized its address then the address assignment will follow equation 2 and 3 for Router and end device respectively.

After address reorganizing the maximum no of child that can be added to that node will be Rm*Rm + Cm out of which (Cm-Rm) are end device and Rm*Rm+Rm is router capable device

If the Node has reorganized its address then the address assigned to its router capable device will be as follows:

For R^{th} routing capable child if R is <= Rm*Rm +1

$$A_{R^{th}} = A_{parent} + P_{cskip}(d).(R^{th} - 1) + 1 \tag{10}$$

Else if $R_m.R_m + 1 < R <= R_m.R_m + R_m$ (11)

Then address is given by

$$A_{R^{th}} = A_{parent} + P_{cskip}(d)R_m^2 + 1 + E \tag{12}$$

Where $E = (C_m - R_m + 1).(R - R_m^2 - 1)$

Network address to the end device is given in a sequential manner and the address given to nth end device is given by the following equation.

$$A_n = A_{Parent} + P_{cskip}(d).R_m^2 + n + F \tag{13}$$

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

And $F = (C_m - R_m + 1).R_m$

All the nodes which are descendent of that reorganizing node will use the subsequent depth and Cskip values. Please refer to **figure3** for network formation, in that node 16 has reorganized its address .Physically the node is at a depth d=1 but its pseudo depth Pd is 2 thus it's Pseudo Cskip $P_{cskip} = 3$. The C_{skip} value for its child is 1 and they are at depth 3 not 2 i.e. Node 17 is physically at level 2 but virtually it is at level 3 with Cskip(3)=1.

That is the sub tree routed at the reorganizing node will have there depth and Cskip value according to the pseudo depth of the address reorganized node and there relative position from that.

Routing in Reorganized Network:

At any Node if it has not reorganized its address then the routing will follow the normal process i.e. it will follow equation 4,5and 6.

If the Node has reorganized its address then routing will be as follows:

If the destination is a descendant of the device, the device shall route the frame to the appropriate child. If the destination is not a descendant, the device shall route the frame to its parent. For a ZigBee router with address A at depth d, and pseudo depth Pd if the following logical expression is true, then a destination device with address D is a descendant:

$$A < D < A + C_{skip}(d-1) \tag{14}$$

If it is determined that the destination is a descendant of the receiving device then it is checked if the destination is a child end device using the formula

$$D > A + R_m^2.P_{cskip}(P_d) + R_m.(C_m - R_m + 1), \tag{15}$$

If it is a child end device then the address N of the next hop device is given by: N=D. (16)

Otherwise,

If the destination address $A < D <= A + P_{cskip}(P_d).R_m^2$

Then the next hop address is given by:

$$N = A + 1 + \left\lfloor \frac{D - (A+1)}{P_{cskip}(P_d)} \right\rfloor \times P_{cskip}(P_d) \tag{17}$$

else the next hop address is given by

$$N = Z + \left\lfloor \frac{D - Z}{(C_m - R_m + 1)} \right\rfloor \times (C_m - R_m + 1) \tag{18}$$

Where $Z = A + 1 + R_m^2 \times P_{cskip}(P_d)$ (19)

All the node which are descendent of address reorganized node shall use there pseudo depth and pseudo Cskip value in place of Cskip in equation 4,5,6,7 for routing purpose, no other changes are needed .

For example in **figure3** say node 4 wants to send some data to Node 24 it will go via the following path.

$4 \Rightarrow 3 \Rightarrow 2 \Rightarrow 1 \Rightarrow 0 \Rightarrow 16 \Rightarrow 23 \Rightarrow 24$.

At Node 16 routing decision will be taken depending on equation (8) at all the other nodes routing will follow equation 4,5,6,7

Again If Node 14 wants to send some data to node 7 it will follow the following path.

$14 \Rightarrow 13 \Rightarrow 9 \Rightarrow 1 \Rightarrow 2 \Rightarrow 7$

In the following **Figure4** and **Figure5** two network configuration with and without address reorganization has been shown.

Where Lm=5, Rm=2, Cm=4.In the following figure all the green circles are router capable device and lines are end device.

Figure4 shows a typical symmetric configuration where all the addresses are occupied, but in real world this may not be the case the network area may not be symmetric and in some part the whole length (here 5) may not be required i.e. at that part the

978-81-8465-152-2/09/$26.00©2009 CODEC

network depth is less than the maximum depth but may require to grow at breadth i.e. some node may require to have more than the maximum no of devices (Cm) in the network.

$C_{skip}(0)$	$C_{skip}(1)$	$C_{skip}(2)$	$C_{skip}(3)$	$C_{skip}(4)$	$C_{skip}(5)$
61	29	13	5	1	0

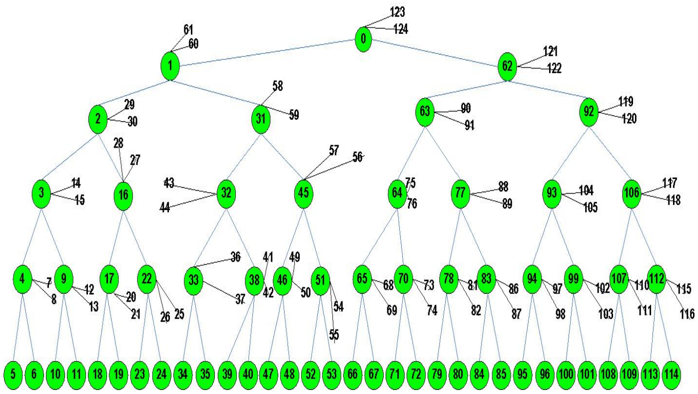

Figure 4: Address Distribution without address Reorganization

In **Figure5** an asymmetric network configuration has been shown where for a part of the network length is 4 and the maximum no of device connected to node 31 is 6.These kind of asymmetric network can be formed in buildings where a part of the ground floor is having canteen hence does not require any networking facility or it can be in mine where the structure is asymmetric.

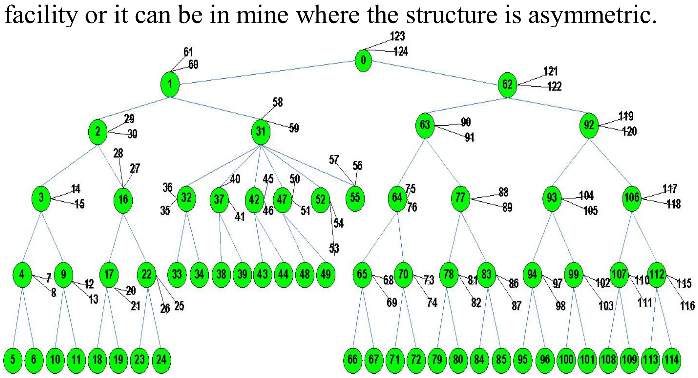

Figure 5: Address Distribution with one level address Reorganization

Address reorganization don't have any effect on other part of the network i.e. node 2, 63 and 92 are at the same level and will have a maximum of 4 child device 2 router capable and two end device and the maximum depth from root at those part will be 5. Address reorganization is also transparent for the parent of node 31 i.e. Node 1, 0 does not need to know anything about address reorganization.

Node 31 has reorganized its address by one level. Physically it is at level 2 with $C_{skip}(2) = 13$ but virtually it is at level 3 with Pseudo depth 3 and $P_{cskip}(3) = 5$ .Node 31 Now have $R_m^2 + 2$ router capable child and 2 end devices

III. CONCLUSION

In this paper we have provided a unified address reorganization scheme which can be used to use WPAN in Business networks such as wireless sensor network in Coal Mine by allowing the network to grow more than the maximum no of child and router capable device chosen for the Network at the time of Network formation.

REFERENCES

[1] A.D Amis, R. Prakash, Thai H P Vuong and Dung T Huynh, "Max-Min dcluster formation in wireless ad-hoc networks", In Proc. IEEE INFOCOM'2000, Tel Aviv, March 2000.

[2] A. Durresi and V. Paruchuri, "Adaptive clustering protocol for sensor networks", IEEE Aerospace Conf. 2005, March 2005, pp. 1-8.

[3] C. J. Alpert, T. C. Hu, J. H. Huang, and A. B. Kahng, "A direct combination of the Prim and Dijkstra constructions for improved performancedriven global routing," University of California, Los Angeles, Dept. Computer Science, Tech. Rep. CSD-920051, 1992

[4] C. E. Perkins, E. Belding-Royer, and S. R. Das, "Ad hoc On-Demand Distance Vector (AODV) Routing", July 2003. RFC 3561.

[5] C. E. Perkins *and P. Bhagwat,* "Highly Dynamic Destination-Sequenced Distance-Vector Routing (DSDV) for Mobile Computers"*, Proceedings of ACM SIGCOMM, 1994.*

[6] C. E. Perkins and Elizabeth Royer, "Ad-hoc On-Demand Distance Vector Routing", Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications, New Orleans, LA, February 1999.

[7] D. Ganeshan, B. Krishnamachari, "Complex Behavior at Scale: An Experimental Study of Low-Power Wireless Sensor Networks", UCLA/CSD-TR 02-0013, UCLA Computer Science, 2002.

[8] Debabrato Giri,Uttam Kumar Roy, "Address Borrowing in Wireless Personal Area Network",Proc. of IEEE International Advanced Computing Conference, (IACC'09,March 6-7),Patiala,India, page no 1074-1079

[9] ZigBee Alliance (ZigBee Document 02130r7) Draft Version 0.90: *Network Specification*, July 2004.

978-81-8465-152-2/09/$26.00©2009 CODEC