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Smart Home System

Controlling electrical appliances via bluetooth ad hoc network communication on Android Platform

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***Abstract*—Technology is endless process and it is being developed continuously. Bluetooth Based Home Automation System[1] is one of the recent technology came in existence. Each technology has several limitations. This paper emphasizes on the limitation of this technology and some advancement in technology to overcome those limitations. This design is presented to overcome the limited range limitation of Bluetooth devices and routing problem. This also focuses on decreasing operational and maintenance cost of the network established. The main idea of paper is to establish wireless ad hoc network for communication between several devices.**

I. INTRODUCTION

Influence of wireless technology is increasing day by day. Because of its mobility, wireless technology is replacing wired network. Technology is changing day by day and advancements are carried out. In today's world, wireless technology plays an important role in the automation. In earlier times, technology or machines were operated manually. These technologies needed human control for operations. Automation makes technology free from human interruption. Home automation is one of technology emerging these days. To make it more operative and efficient, cost is reduced by low cost communication technology like Bluetooth, Wi-Fi. Bluetooth is nice technology to use in home automation. This is no operational cost technology, common in use and working in range up to 100 meters.

Many few issues are considered for designing for home automation. These issues are mentioned below: (1) System must be scalable to integrate new devices (2) User Interface must be user friendly (3) Easy setup (4) Easy to monitor and control (5) Diagnostic service so that problems can be tracked down (6) Efficient communication (7) Cost Effective.

Yavuz and Hasan [2] designed telephone and PIC based control system communication took place via dedicated telephone lines, not using Bluetooth [3][4]. Other technologies [5][6] in home automation is web based automation. These had limitations of high cost. Al-Ali and Al-Rousan[7] presented low cost java based home automation system without highlighting low level devices of peripherals. Sriskanthan proposed home automation that was based on controlling home appliances by pc via Bluetooth technology [10]. Then finally R. Piyare and M. Tazil introduced home automation by using Symbian cellphones via Bluetooth [1]. This design has several limitations like range limitation and limited platform.

This paper introduces latest technology android platform mobiles, smartphones and tablets to control electrical appliances via Bluetooth. This design overcame the limitations of earlier Bluetooth home automation systems which was Bluetooth limited range and limited platform. These problems are considered, studied and solved in this design.

II. SYSTEM ARCHITECTURE

Basically, the ad hoc network [11] is infra-structured. It is having concept of cluster of nodes and all nodes having the role of intermediate nodes. These nodes will be having slave node and these nodes will be in the disconnected state to reduce power consumption and to provide route to other nodes. These nodes will be permitted by domain node that is the android node having the authority to permit the nodes to communicate in the network. This node will be mobile node and this node is included in the routing table records.

These main nodes can directly or indirectly communicate with other main nodes. These nodes will always be free for connection. These nodes will be connected, perform function and then disconnected again.

This design of home automation system consists of two main hardware components: (1) Android Node [9] (2) Arduino Node [8].

A. Android Node

Android Nodes are the mobile nodes that work on Android platform. These nodes use the mobile phone as the node for communication. These nodes are basically called

Domain Nodes. These nodes are similar to the android nodes but these nodes are having special power of recognizing the nodes and permitting the nodes to be a part of the ad hoc network. This node will behave as a normal node but also will have special authorization power for blocking and permitting devices for communication in the network. This node is also having power of defining the electrical appliances used with the Arduino nodes and their configuration. This configuration is to be carried out individually with each Android node, since there is no transmission of details to the network for configuration of these electrical appliances.

B. Arduino Node

Arduino Nodes is the major part of and most used in this network. These nodes will be connected to the electrical circuits or appliances. These nodes will be playing the following role of slave node. Slave Nodes are the arduino nodes nodes will be simple nodes which will having many roles like working as an intermediate node and it can work as destination node. These nodes cannot behave as source node since these devices are not having the configuration of the electrical appliances and these nodes will be directly connected to the electrical appliances. Some roles of the arduino nodes are given below in details:

1) Intermediate Nodes: These nodes are compatible to the role of intermediate nodes to give extension to the range of the network. These nodes will be receiving the control message and forward the control message to the next node in the path of destination node.

2) Destination Nodes: These nodes are compatible to the role of destination nodes to control electrical appliances. These nodes are directly connected to the electrical appliances.

Limitation of these nodes is that these nodes cannot behave as source node for controlling electrical appliances. These nodes will receive the control signals and use store and forward technique.

III. NETWORK FORMATION

Initially, there is one mobile node that is domain node. For a startup of the network, it will require atleast one arduino node to control electrical appliances. Firstly it will check for nodes available. Then it will pair nodes. This process is a sequential process and it is carried out separately for every node. If any arduino and normal android nodes found, then it will pair that node and permit this node. Domain Nodes will be having the authority of permitting new nodes for communication in the network and blocking of the nodes communicating in the existing network. The blocking includes temporary blocking and permanent removal. Temporal blocking is defined as blocking in which the nodes are to be blocked for a temporary duration and configuration of the electrical appliances is not removed. Permanent blocking is defined as blocking in which the nodes are to be blocked permanently until unless they are permitted again and configuration of the electrical appliances is removed. Now, domain node send permit message to other node which is to be introduced new in network. The message packet here is defined in the table2. The message content includes the MAC address of all the nodes already permitted. Now, the new node receives the message packet and extracts the data from packet. This data includes the self-address of the new node and all the nodes that are already permitted in the network except the address of domain node. Since all nodes except the domain node are fixed and domain node is in mobile mode, it will require frequent route checking and finding new routes.

Now, the permit message is broken into separate parts and data is extracted and this data is updated in the routing table stored in the node. This node then calls for initial update message. Initial update message is the message packet that is generated by this new node and it sends this to its closest available node by searching in the routing table from top to down. Firstly it searches and tries to connect the nodes available. If node is connected then it will send initial update message. This message contains the address of new node. The node connected to this node receives the initial update message and updates its routing table by adding the distance equal to 1 hop. Now this node sends back the initial update acknowledgement packet which is basically divided into many pieces and each piece is transmitted individually. Each piece of message packet consists of the information for one different node. This information includes the address of the node, address of next node, address of previous node, distance between the nodes and the sequence number. This is having the continuity bit that is for checking whether there is another piece of message packet is pending for reception or not. If it is 0, then new node receives this piece of message packet and closes the connection with the transmitting node. If it is 1, then new node remains in connected state and receives message and update the routing table. Now, the node that was already permitted sends the initial forward message packet to all nodes that were permitted at that time. This message includes the details of the new node address, next node, previous node, distance, sequence number. This message is generated and sent to all nodes sequentially. Now the network is prepared, this process is repeated again and again when new nodes are to be introduced to the network. Now, the network is ready for communication. Domain node or simple android nodes will send control message in the form of message packet. These nodes will search out the destination node by searching available devices. Two cases arise here:

A. Destination Node out of reach

Domain Node or android node searches out for a destination node. It will check whether the node is available in device discovery. In this case, destination node is not in the direct reach of the source node. In this, it will send the control message packet to the first node available in the searching of the node. This node receives the packet and verifies that it is for other node or for itself. In this case, it

finds that packet is for other node. So, this node looks into routing table and looks for the record of the destination in table and fetches next node. Now, it will try to connect to next node and send the packet to it. This process will go on until unless control message packet is reached to its destination node.

B. Destination Node in coverage

In this case, destination node is in direct coverage or reach of the android node or domain node. Source node will send it directly to destination node and destination node will implement it by fetching the control message stored between the two side bits. Now, this control message contains the pin number to which the electrical appliance is connected and the status of the pin to be set.

IV. SOFTWARE DEVELOPMENT

A. Flow Chart

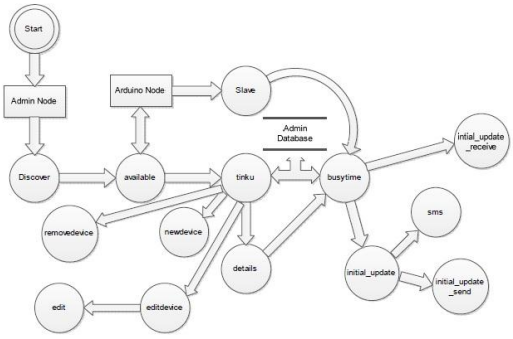

Figure 1. Flow Chart of the system

B. Graphics User Interface(GUI) Module

The most important feature of our application is to provide easy to use user interface and using concept of multi-threading for making user not to wait for long time. By using the GUI package, we are able to configure the electrical appliances connected on the arduino nodes from domain node. This makes the system easy to configure and operate from domain node. Figure 2 illustrates some designs for the graphical user interface.

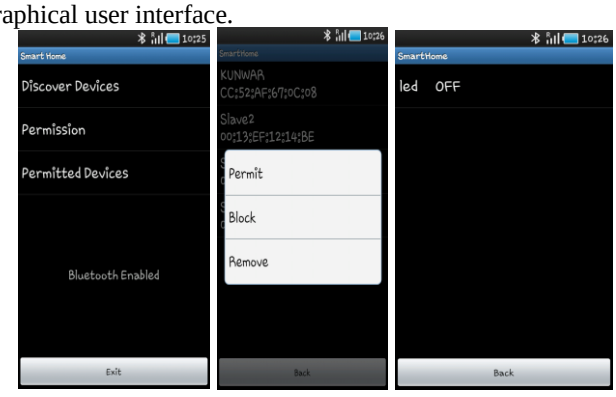

Figure 2. Cell Phone GUI for controlling home appliances

Table 1. Routing Table of Nodes

Parameters	Routing Table Format						
Field Name	Source Node	Destination Node (Primary Key)	Previous Node	Next Node	Distance	Sequence No.	Status
Size(Bytes)	18	18	18	18	2	2	2
Content Type	MAC Address (Character)	MAC Address (Character)	MAC Address (Character)	MAC Address (Character)	Integer	Integer	Integer

V. ROUTING TABLES

Ad hoc network routing was one of the issue that is to be resolved in this design. The solution is to use routing table 1.

VI. MESSAGE PACKETS

Message packets are the messages along with some other data which is of no use on reception of data. Message packets are basically categorized as mentioned below and the details about the size, Name, type of storage of each parameter of the packets is mentioned in the list of tables:

A. Initial Message/Permit message

This is basically message used for permitting the nodes for communication in the network. This contains the address of all permitted nodes except the domain node and address of the new node.

Table 2. Initial Message Format

Parameters	Field name	Size(Bytes)	Data Type
Initial Message Format	Start Bit	1	Special Character
	Destination Node	6	MAC Address
	Side Bit	1	Special Character
	Message	1(Minimum)	Character
	Side Bit	1	Special Character
	Sequence No.	2	Integer
	Control Bit	2	Integer
	Parity Bit	2	Integer
	Stop Bit	1	Special Character

B. Initial update message

Table 3. Initial Update Message Format

Parameters	Field name	Size(Bytes)	Data Type
Initial Update Message Format	Start Bit	1	Special Character
	Destination Node	6	MAC Address
	Sequence No.	2	Integer
	Control Bit	2	Integer
	Parity Bit	2	Integer
	Stop Bit	1	Special Character

This is basically the update message that is being transmitted by the new node that is allowed for communication. This node searches the nodes available according to the records of routing table. It will send the message packet to the first connected device and wait for the initial acknowledgement message. This message contains the address of the new node. As it is received by some permitted node, that node starts transmission of initial acknowledgement message.

C. Initial Acknowledgement message

Table 4. Initial Acknowledgement Message Format

Parameters	Field name	Size(Bytes)	Data Type
Initial Acknowledgement Format	Start Bit	1	Special Character
	Source Node	6	MAC Address
	Destination Node	6	MAC Address
	Previous Node	6	MAC Address
	Next Node	6	MAC Address
	Side Bit	1	Special Character
	Distance	1(Minimum)	Character
	Side Bit	1	Special Character
	Sequence No.	2	Integer
	Continuity Bit	2	Integer
	Control Bit	2	Integer
	Parity Bit	2	Integer
	Stop Bit	1	Special Character

This message packet is having the records of the routing table of the node who receives the initial update message. This packet is very large and it needs very high buffer size. So, this packet is divided into many pieces via using another parameter named continuity bit. This bit is used for the verification whether any other piece of packet is available for reception or not. If continuity bit is 1 then there is some packet that is to be received for full updating of the routing table of newly permitted node else the node have received all packets pieces and it is ready for communication. Now, the node will forward the initial update message received by converting it into initial forward message and send it to the other previously permitted nodes.

D. Initial forward message

This message packet is forwarded to all previously permitted nodes serially. This packet consists of the record of the new node. As all nodes receive this message packet, network is completely ready for communication.

E. Control message

This message packet is basically used for controlling electrical appliances. This message packet is the having the main focus of the network. This is generated by the domain node or android node only. Arduino nodes can receive this packet and retransmit it without making any changes until unless it reaches its final destination node where it is implemented and acknowledgement packet is generated.

Table 5. Initial Forward Message Format

Parameters	Field name	Size(Bytes)	Data Type
Initial Forward Message Format	Start Bit	1	Special Character
	Source Node	6	MAC Address
	Destination Node	6	MAC Address
	Previous Node	6	MAC Address
	Next Node	6	MAC Address
	Side Bit	1	Special Character
	Distance	1(Minimum)	Character
	Side Bit	1	Special Character
	Sequence No.	2	Integer
	Control Bit	2	Integer
	Parity Bit	2	Integer
	Stop Bit	1	Special Character

F. Control acknowledgement message

This message packet is basically confirmation or acknowledgement message generated by the destination node of the control message. This is for confirmation whether the message received is implemented or not.

Table 6: Control Message Format

Parameters	Field name	Size(Bytes)	Data Type
Message Format	Start Bit	1	Special Character
	Source Node	6	MAC Address
	Destination Node	6	MAC Address
	Side Bit	1	Special Character
	Message	1(Minimum)	Character
	Side Bit	1	Special Character
	Sequence No.	2	Integer
	Control Bit	2	Integer
	Parity Bit	2	Integer
	Stop Bit	1	Special Character

If not then it will send status "fail" else if the message is implemented it will send "done" as status in this message and this message is sent back to the source node that have generated the control message.

VII. SECURITY

Security is kept in mind while designing this model. Physical addresses are used in this for communication which makes it more secure than earlier designs. This provides more security against unauthorized access to the network.

VIII. ERROR DETECTION

Error detection technique is also included in this design. The technique used is to detect error is parity bit check.

Table 7. Control Message Acknowledgement Format

Parameters	Field name	Size(Bytes)	Data Type
Control Message Acknowledgement Format	Start Bit	1	Special Character
	Source Node	6	MAC Address
	Destination Node	6	MAC Address
	Side Bit	1	Special Character
	Status	1(Minimum)	Character
	Side Bit	1	Special Character
	Sequence No.	2	Integer
	Control Bit	2	Integer
	Parity Bit	2	Integer
	Stop Bit	1	Special Character

Parity bit check is implemented on receiving messages and sending messages. If parity bit check shows error in transmission, transmission is carried out again.

IX. ADVANTAGES

This design is having advantages over Bluetooth Based Home Automation System using cell phones: (1) Error Detection, (2) Wide Platform, (3) Less operational cost, (4)Less maintenance cost, (5) Less installation cost, (6) Temporary & permanent Blocking, (7) More Security.

X. CONCLUSION

In this paper we have introduced design and implementation of a low cost, flexible and wireless solution to the home automation systems till now. The system is secured for access from any user since it works using physical address. The users are required to pair network devices before using them in network. These devices can be blocked or permanently removed from network. This system can be used as for the controlling electrical appliances with no range limitations. This design is practical tested with two arduino BT nodes and one android node. For future work it is recommended to have reducing the delay and power consumption, efficient routing, voice based control.

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