Voice Call Implementation Using Bluetooth Scatternet

Vishal K. Gangatre
Sinhgad College Of Engineering, Pune – 411041, Pune, India

Chetan Ghorpade
Sinhgad College Of Engineering, Pune – 411041, Pune, India.

***Abstract*— Almost all cell phones are having Bluetooth capabilities nowadays. A number of usage models such as File transfer, LAN access, Wireless headset, Cordless phone are defined in Bluetooth profile documents. A usage model is described by a set of protocols that implement a particular Bluetooth-based application. According to "Wireless Headset" usage model, the Bluetooth-capable headset can be connected wirelessly to a PC or mobile phone, offering a full-duplex audio input and output mechanism. This usage model is known as the "Ultimate Headset". This usage model can be considered as a backbone or framework for designing our application. Using the application , users will be able to communicate free of cost within the Scatternet Network. Since the call does not deal with the GSM Network, the communication between them will be free of cost. To increase the range of the Bluetooth network, this application is going to use the Scatternet, which will result in more coverage for free communication.**

***Keyword*— Bluetooth(IEEE 802.15.1), Scatternet , Protocol Stack, Ultimate Headset .**

I. INTRODUCTION

Bluetooth is a kind of Wireless personal area network (WPAN) used to convey information over short distances among a private, intimate group of participant devices. A connection made through a WPAN involves little or no infrastructure or direct connectivity to the world outside the link. This allows small, power-efficient, inexpensive solutions to be implemented for a wide range of devices.

The IEEE 802.15.1 standard specifies the architecture and operation of Bluetooth devices. A number of usage models such as File transfer, LAN access, Wireless headset, Cordless phone are defined in Bluetooth profile documents. A usage model is described by a set of protocols that implement a particular Bluetooth-based application. According to "Wireless Headset" usage model, the Bluetooth-capable headset can be connected wirelessly to a PC or mobile phone, offering a full-duplex audio input and output mechanism. This usage model is known as the "Ultimate Headset". This usage model can be considered as a backbone or framework for developing our project.

The paper focuses on developing an application. Through the application two mobile users can communicate (i.e. make call) within the Bluetooth network. As this does not deal with the GSM Network, the communication between them will be free of cost. To increase the range of the Bluetooth network, this application is going to use the Scatternet. When two or more independent, non-synchronized Bluetooth piconets overlap, a Scatternet is formed allowing inter-piconet communication. Using Scatternet the device in one Piconet can communicate with the device in another piconet. This will increase the range of Bluetooth Network. The application can be mainly used for free communication within organizations, colleges, departments, offices, etc. Further the application usage can be extended for Digital Notice Board , Free Video Calls, Free Messaging, Conference Calls.

A. What is Bluetooth ?

Bluetooth wireless technology is a short-range communications system intended to replace the cable(s) connecting portable and/or fixed electronic devices. Key features are robustness, low power, and low cost. Many features of the core specification are optional, allowing product differentiation. The Bluetooth core system consists of an RF transceiver, baseband, and protocol stack. The system offers services that enable the connection of devices and the exchange of a variety of classes of data between these devices. The current specification running is Bluetooth version 2.0, released in 2004.

Bluetooth operates in the unlicensed ISM band at 2.4 GHz. The system employs a frequency hop transceiver to combat interference and fading and provides many FHSS carriers. RF operation uses a shaped, binary FM modulation to minimize transceiver complexity. The symbol rate is 1 Megasymbol per second (Ms/s) supporting the bit rate of 1 Megabit persecond (Mb/s).

B. The Bluetooth Protocol Stack

The Protocol Stack is the backbone in the working of Bluetooth. The usage models viz. Specification of Bluetooth have their individual protocol stack configuration. The ultimate objective of the specification is to allow applications written in a manner that is conformant to the specification to interoperate with each other. To achieve this interoperability, matching applications (e.g., corresponding client and server

application) in remote devices must run over identical protocol stacks. The following protocol list is an example of a (top-to-bottom) protocol stack supporting a business card exchange application: vCard → OBEX → RFCOMM → L2CAP → Baseband. This protocol stack contains both an internal object representation convention, vCard, and "over-the-air" transport protocols, the rest of the stack.

Different applications may run over different protocol stacks. Nevertheless , each one of these different protocol stacks use a common Bluetooth data link and physical layer. Fig.1 shows the complete Bluetooth protocol stack as identified in the Specification on top of which interoperable applications supporting the Bluetooth usage models are built. Not all applications make use of all the protocols shown in Figure 1. Instead, applications run over one or more vertical slices from this protocol stack. Typically, additional vertical slices are for services supportive of the main application, like TCS Binary (Telephony Control Specification), or SDP (Service Discovery Protocol).

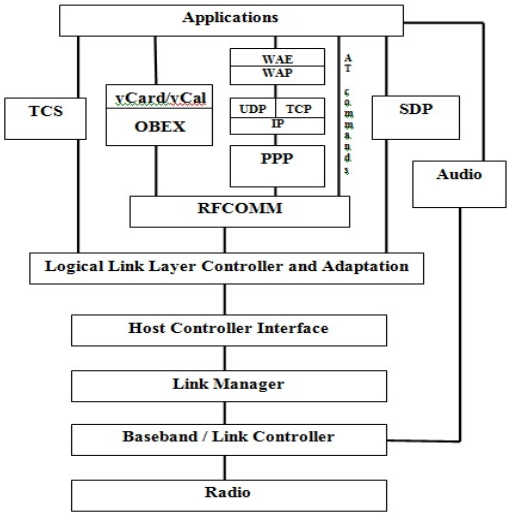

Fig 1: Bluetooth Protocol Stack

It is worth of mentioning that Figure 1 shows the relations how the protocols are using the services of other protocols when payload data needs to be transferred over air. However, the protocols may also have some other relations between the other protocols. E.g., some protocols(L2CAP, TCS Binary) may use LMP (Link Manager Protocol) when there is need to control the link manager.

II. The Ultimate Headset

The IEEE 802.15.1 standard specifies the architecture and operation of Bluetooth devices. For Bluetooth devices there are a number of usage models such as File transfer, LAN access, Wireless headset, Cordless phone defined in Bluetooth profile documents specified by IEEE 802.15.1 . A usage model is described by a set of protocols that implement a particular Bluetooth-based application. Each usage model utilizes the protocol stack in different configuration. The protocol stack configuration for Wireless Headset usage model is shown in Fig. 2.

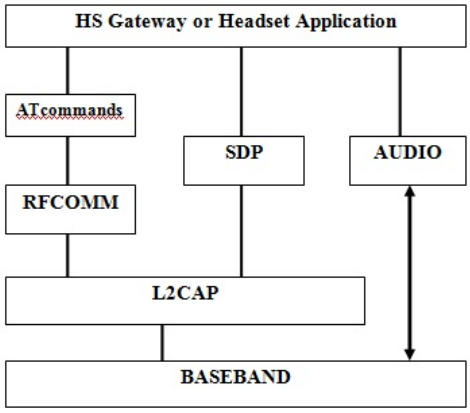

Fig. 2 : Configuration of Protocol Stack for Headset Model Usage

Audio data in SCO packets is routed directly to and from Baseband and it does not go through L2CAP. Audio model is relatively simple within Bluetooth; any two Bluetooth devices can send and receive audio data between each other just by opening an audio link. This usage model is known as the "Ultimate Headset".

C. Project Idea:

The theme of the project is to integrate the "Ultimate Headset" Usage Model within our application to establish a call without using the GSM Network. Thus the communication will be free of cost. The communication will be just like the data transfer in Bluetooth devices.

III. Scatternet

A scatternet is a type of ad-hoc computer network consisting of two or more piconets. A piconet is the type of connection that is formed between two or more Bluetooth-enabled devices such as modern cell phones or PDAs. Bluetooth enabled devices are "peer units" in that they are able to act as either master or slave. However, when a piconet is formed between two or more devices, one device takes the role of 'master', and all other devices assume a 'slave' role for synchronization reasons. Piconets have a 3-bit address space, which limits the maximum size of a piconet to 8 devices ($2^3 = 8$), i.e. 1 master and 7 slaves.

A scatternet is a number of interconnected piconets that supports communication between more than 8 devices. Scatternets can be formed when a member of one piconet

(either the master or one of the slaves) elects to participate as a slave in a second, separate piconet. The device participating in both piconets can relay data between members of both ad-hoc networks. However, the basic bluetooth protocol does not support this relaying - the host software of each device would need to manage it. Using this approach, it is possible to join together numerous piconets into a large scatternet, and to expand the physical size of the network beyond Bluetooth's limited range.

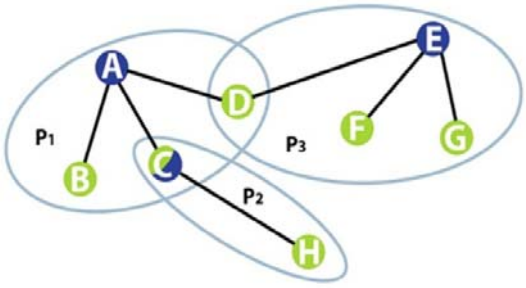

Fig. 3: Scatternet

The architecture of scatternet is shown in Fig. 3 which shows that "when two or more independent, non-synchronized Bluetooth piconets overlap, a Scatternet is formed allowing inter-piconet communication". Using Scatternet the device in one Piconet can communicate with the device in another piconet.

The scatternet network will be used in our project to increase the network of the Bluetooth for free communication.

IV. Architecture And Mathematical Model

The block diagram in Fig. 4 depicts various modules in the project and their interaction. The architecture has two core modules , the Scatternet Module and the Application Module. The modules form the base of the project.

The Scatternet Module uses the three modules viz. The Generate User List , Scatternet Formation ,Establish Link for forming the Scatternet Network. The application will use the Scatternet Module to interact with the Scatternet.

The Application Module provides services to the user such as dialing a call , receiving a call , refreshing the users list and interaction with the scatternet.

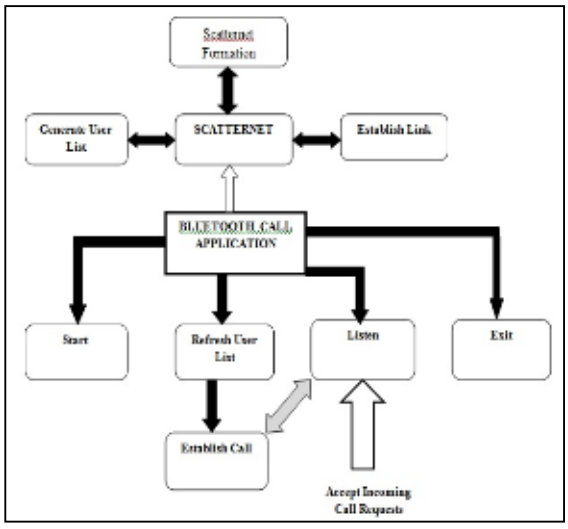

Fig. 4: Block Diagram of "Voice Call Implementation Using Bluetooth Scatternet"

D. Mathematical Model:

Let 'S' be a system that describe " Voice Call Implementation Using Bluetooth Scatternet" . It contains the following Modules.

$$S=\{ INPUT , S_1 , S_2 , S_3 , S_4 , S_5 , OUTPUT \}$$

where , S_1 : Scatternet Formation
S_2 : Generate User List
S_3 : Refresh User List
S_4 : Establish Call
S_5 : Listen

1) Input Of The System :

INPUT = { App_IconCLK , $\mathbf{P_{1..N}}$ **,** Exit_CLK **}**

Where, App_IconCLK= Click on the Application Launch Icon , Exit_CLK = Click on the Application Exit Icon , $\mathbf{P_{1..N}}$ = Piconets from 1 to N.

2) Set Theory for Module S1 (Scatternet Form^n) :

$\mathbf{S_1}$ **= {.....}**

Identify Inputs : $\mathbf{ip_1}$ = { P | P is a Piconet }
= { P_1,P_2,P_3,.....}

Identify Outputs : $\mathbf{op_1}$ = {SCATTERNET}

where , SCATTERNET = formed Scatternet using the provided piconets P_1,P_2,P_3,..

Identify Functionality :
$\mathbf{P_1}$ = {form_SCT}
$\mathbf{f_1}$: **form_SCT**(P_1,P_2,P_3,.....)={ SCATTERNET }

Identify Initial Condition :
$\mathbf{s_{01}}$ = {Active Piconets with all ON Bluetooth nodes}

Identify Success State (Final State) :
$\mathbf{e_1}$ = { Scatternet Formation }

Identify Failure State :
exception$_1$ = { 1. Unable to form Scatternet
Action: Try Again }

Now , set **S_1** is modified as,
S_1 = {ip$_1$, op$_1$, P$_1$, s$_{01}$, e$_1$, exception$_1$ }

3) Set Theory for Module S2 (Generate User List) :

S_2 = {.....}

Identify Inputs : **ip$_2$** = { SCATTERNET }

Identify Outputs :
op$_2$ = {U | U is an user in scatternet}
= {U_1,U_2,U_3.....}

Identify Functionality :
P$_2$ = {gen_UL}
f$_1$: **gen_UL**(SCATTERNET)= { U_1,U_2,U_3.....}

Identify Initial Condition :
s$_{02}$ = {Formed Scatternet}

Identify Success State (Final State) :
e$_2$ = { User List Generated }

Identify Failure State :
exception$_2$ = { 1. User List Malfunction
Action: Search Again }

Now , set **S_2** is modified as,
S_2 = {ip$_2$, op$_2$, P$_2$, s$_2$, e$_2$, exception$_2$ }

4) Set Theory for Module S3 (Refresh User List) :

S_3 = {.....}

Identify Inputs :
ip$_3$ = { RUL_CLK , SCATTERNET }

Identify Outputs : **op$_3$** = {U | U is an user in scatternet}
= {U_1,U_2,U_3.....}

Identify Functionality :
P$_3$ = {gen_UL}
f$_1$: **gen_UL**(SCATTERNET)= { U_1,U_2,U_3.....}

Identify Initial Condition :
s$_{03}$ = {Formed Scatternet}

Identify Success State (Final State) :
e$_3$ = { User List Generated }

Identify Failure State :
exception$_3$ = { 1. User List Malfunction
Action: Search Again }

Now , set **S_3** is modified as,
S_3 = {ip$_3$, op$_3$, P$_3$, s$_{03}$, e$_3$, exception$_3$ }

5) Set Theory for Module S4 (Establish Call) :

S_4 = {.....}

Identify Inputs : **ip$_4$** = { U_{src} , U_{dest} }
where , U_{src} = Source Node
U_{dest} = Destination Node

Identify Outputs : **op$_4$** = { CALL(U_{src} , U_{dest}) }
where , CALL = Call Between source and destination nodes.

Identify Functionality :
P$_4$ = {estb_CALL}
f$_1$: **estb_CALL**(U_{src} , U_{dest}) = { CALL(U_{src} , U_{dest}) }

Identify Initial Condition :
s$_{04}$ = {Formed Scatternet}

Identify Success State (Final State) :
e$_4$ = { Call Established }

Identify Failure State :
exception$_4$ = { 1. Call Failure
Action: Wait , Try Again }

Now , set **S_4** is modified as,
S_4 = {ip$_4$, op$_4$, P$_4$, s$_{04}$, e$_4$, exception$_4$}

6) Set Theory for Module S5 (Listen) :

S_5 = {.....}

Identify Inputs : **ip$_5$** = { Listen_Mode , incoming_call}

Identify Outputs : **op$_5$** = { Listen_Mode , estb_CALL }

Identify Functionality :
P$_5$ = {estb_CALL , Listen_Mode}
f$_1$: **Listen_Mode( ).**
f$_2$: **estb_CALL**(U_{src} , U_{dest}) = { CALL(U_{src} , U_{dest}) }

Identify Initial Condition :
s$_{05}$ = {Formed Scatternet}

Identify Success State (Final State) :
e$_5$ = { Call Established ,
Listen Mode }

Identify Failure State :
exception$_5$ = { 1. Call Failure
Action: Wait , Try Again }

Now , set S_5 is modified as,

$S_5 = \{ip_5 , op_5 , P_5 , s_{05} , e_5 , exception_5 \}$

7) OUTPUT OF THE SYSTEM :

OUTPUT = { App_ON, BTH_ON, App_OFF, BTH_OFF , SCATTERNET , CALL(U_{src} , U_{dest}) }

where , App_ON = Application On
BTH_ON = Bluetooth On
App_OFF = Application Off
BTH_OFF = Bluetooth Off
SCATTERNET=Formed Scatternet
CALL(U_{src} , U_{dest}) = Established Call

8) Mathematical Model :

Let 'S' be a system that describe "Voice Call Implementation Using Bluetooth Scatternet" .

S = { INPUT, S_1 , S_2 , S_3 , S_4 , S_5 , OUTPUT,
$ip_{1....5}$, $op_{1....5}$, $P_{1....5}$, $s0_{1....5}$, $e_{1....5}$,
$exception_{1....5}$, App_IconCLK , Exit_CLK ,
App_ON , BTH_ON , App_OFF , BTH_OFF,
start_APP ( ) , close_APP ( ) ,
$P_{1..N}$, SCATTERNET , form_SCT ( ) ,
$U_{1..N}$, gen_UL ( ) ,U_{src} , U_{dest} , estb_CALL ( ),
CALL(U_{src} , U_{dest}) , RUL_CLK , Listen_Mode ,
IncomingCall , Listen_Mode ( )
}

9) Venn Diagram :

The Venn diagram in Fig. 4 shows the mapping between the pair of calls set to the list of users. This is one-to-many mapping.

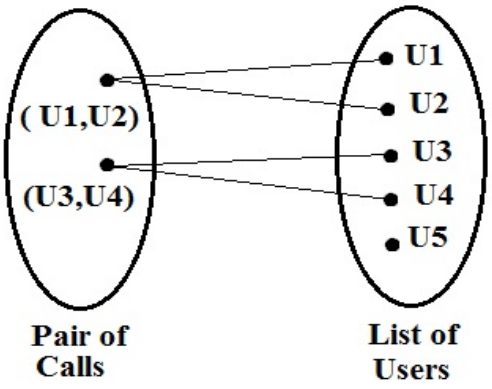

Fig. 5 Mapping Between Call_Set and User_Set

However , there will be ono-to-one correspondence between different users in the call relation, which means that one user can call only one user at a time.

V. CONCLUSION

In this paper , we have proposed that the Bluetooth Stack Protocol configuration for the Headset Usage Model ("Ultimate Headset") can be used to implement a real time call connection between two mobile Bluetooth nodes.

The Scatternet Implementation in the same will provide a larger network to user nodes for free communication .

REFERENCES

[1]. Yong Liu, Myung J. Lee,Tarek N. Saadawi ,*A Bluetooth Scatternet-Route Structure for Multihop Ad Hoc Networks* ,IEEE Journal On Selected Areas In Communications, Vol. 21, No. 2, February 2003.

[2]. Sabeen Tahir, Abas Md Said, and Sheikh Tahir Bakhsh , *Link Repairing for Inter-Piconet Communication Technique in Bluetooth Scatternet*, International Journal of Computer and Electrical Engineering, Vol. 4, No. 4, August 2012.

[3]. Hemali Kotak1, Hiteishi Diwanji ,*A New Approach to Efficient Bluetooth Scatternet Formation In Adhoc Wireless Network,* International Journal of Technology And Engineering System(IJTES) Issue. 1, Vol. 1, May 2009.

[4]. Zhifang Wang · Robert J. Thomas · Zygmunt J. Haas, *Performance comparison of Bluetooth scatternet formation protocols for multi-hop networks,* Wireless Network (2009) 15:209–226.

[5]. Muralidhar Medidi Jonathan Campbell ,*Energy-Efficient Bounded-diameter Tree Scatternet for Bluetooth PANs,* Proceedings of the IEEE Conference on Local Computer Networks 30th Anniversary (LCN'05).

[6]. Chih-Yung Chang, Hsu-Ruey Chang *"Adaptive Role Switching Protocol for Improving Scatternet Performance in Bluetooth Radio Networks"* IEEE Transactions on Consumer Electronics, Vol. 52, No. 4, November 2006.

[7]. R.Dhaya, Dr.V.Sadasivam, Dr.R.Kanthavel, *Reliable Point to Multipoint Hierarchical Routing in Scatternet Sensor Network,* International Journal of Advanced Networking and Applications.Volume: 02, Issue: 04, Pages:738-744 (2011).

[8]. Sheikh Tahir Bakhsh, Halabi Hasbullah, *Dynamic Stable Relay Selection in Bluetooth Scatternet*, 978-1-4244-6716-7/10 2010 IEEE.

[9]. Muralidhar Medidi Yuanyuan Zhou, *Maintaining an Energy-effcient Bluetooth Scatternet,* 1-4244-0198-4/06 2006 IEEE.

[10]. Sourav Banerjee, Dipansu Mondal, Sumit Das and Ramendu Bikash Guin, *Real-Time Video Streaming Over Bluetooth Network Between Two Mobile Nodes,* IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 3, No 11, May 2010.