Bluetooth Scatternets and Simulation

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Bluetooth Devices

➢ Bluetooth is a low power and short range technology that has been a promising technology since 1999.
➢ Is a low cost wireless communication module small enough to fit inside mobile phones, laptops, hand holds, coffee maker etc.
➢ Originally created as a cable replacement.
➢ Very popular in Personal Area Networks (PAN)
The physical communication is done via Frequency Hopping Spread Spectrum over Time Division Duplexing (FHSS/TDD).

- Frequency is within the unregulated Industrial, Science and Medical (ISM) band 2.4GHz at a data rate of 720Kb/s.
- Each channel is divided in 625ms slots.

<table>
<thead>
<tr>
<th></th>
<th>Ch(n)</th>
<th>Ch(n+1)</th>
<th>Ch(n+2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Master</td>
<td>Tx</td>
<td>Rx</td>
<td>Tx</td>
</tr>
<tr>
<td>Slave</td>
<td>Rx</td>
<td>Tx</td>
<td>Rx</td>
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625 ms
Bluetooth Piconets

- A piconet is a collection of Bluetooth devices connected in an ad-hoc fashion.
- Each piconet is compound of 8 BT devices, one master and seven slaves.
- One device may be master in one piconet and slave in 7 other piconets.
- There is no direct communication between slaves. All the communication is made through the master node.
- Each piconet share an unique frequency hopping pattern determined by the master's Bluetooth Device Address (48bits) and Clock.
Bluetooth Piconets (cont)

- Master is continuously polling the slaves for communication.
- The master assigns an unique internal addresses to each slave (3 bits) in its piconet.
- The slave can communicate in a slot only if the master has addressed it in a previous slot.
- Packets can be 1, 3, 5 slots long and are transmitted in consecutive slots. A packet is more than one slot long if the communication is asynchronous.
Bluetooth Piconet Representation

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Bluetooth Scatternets

- A scatternet is formed with the linking of one or more piconets.
- This linking is formed by the sharing of a common device called the Bridge or Relay Node.
- A device can be both a master and a slave in different piconets.
Proposed Packet Header

- **MAC_ADDR**: Is the Bluetooth Device Address (48 bits)
- **FF** (forward flag): The master needs to know whether a message is for another slave or for itself. (1 bit)
- **DA** (Destination Address): Represents the internal piconet unique Mac Address of the slaves assigned by the master in a piconet. (3 bits)
- **BF** (Broadcast Flag): Determines when a packet is an inter piconet broadcast packet. (1 bit)
- **RVF** (Routing Vector Field): Contains the logical path to travel from one node in a piconet to another node in another piconet.
There are 4 types of communication in the routing.

- Intra Piconet Unicast Packet (slave to slave)
- Intra Piconet Broadcast (slave to complete piconet)
- Inter Piconet Unicast Packet (piconet to piconet)
- Inter Piconet Broadcast (piconet to all scatternet nodes)
Slave to Slave (Intra Unicast)

- The source slave writes its own MacAddr, set FF=1, and set DA with the destination MacAddr.
- The master receive the message and notice the FF flag, then it replace the MacAddr field with its MacAddr and send the message to the slave with MacAddr = DA.
Slave to Broadcast (Intra piconet)

- Source Slave writes its own MacAddr, set FF=1, and DA=000
- The master receive the message and notice the FF, then replace the MacAddr with its own, and send the message to all the nodes in its piconet.
The Routing Vector Field (RVF)

- The RVF or logical channel contains the logical path from one node in a piconet to another node in another piconet to send unicast packets.
- The bridge node has to assign an internal LocId to each master where it is connected. This is how it identifies in which piconet it is connected.
- The RVF is a sequence of tuples (LocId, Mac_Addr) filled by the relay nodes. Every time an inter piconet broadcast message is sent, the relay nodes append the tuple to the RVF. Later the destination nodes may use this path to send back an unicast message.
Piconet to Piconet (Inter Unicast)

- The source device sends the message with its own MacAddr, set FF=1, BF=0, DA=MacAddr of the relay to the next piconet, and RVF contains the logical path to the destination device after its piconet.
- Master sends the message to the relay node.
- Relay node extracts the next pair (LocId, Mac_Addr) from the RVF, set DA=Mac_Addr, and sends the message to LocId master.
- The previous is repeated until the RVF is empty. In that moment the destination device is reached.
Inter-Piconet Unicast Example from A to D.
Piconet to Piconet Broadcast

- Source device creates a packet with its own Mac_Addr, set FF=1, set BF=1, set DA=000. Then send it to the master.
- Master notice the BF=1, and send the packet to all its intra piconet slaves with BF=1.
- If a relay receive the broadcast, then it forwards the message to all the master it is connected.
- Every time a device receive the message it include its MacAddr to the RVF.
Bluetooth Performance Challenges

- Syncronization: Bridge nodes waste time when switching from one piconet to another. Time is required to synchronize the clocks with the master.
- Avoid simultaneous request to the bridge node from different piconets.
- Scheduling algorithms has to adapt to variations in traffic intensity.
- Memory: The scheduling algorithms should optimize memory usage.
My Simulation

➢ My simulation is inspired on the routing technics proposed in: “A routing Vector Method for routing in Bluetooth Scatternets” and “A Bandwith Efficient Packet Transmision Algorithm for Bluetooth Scatternets”.
➢ Though the most of the influence came from the RVM paper.
MacAddr: Is represented by an UDP port of the computer. (16 bits)
FF: Forward Flag (1 bit)
DA: Destination Address (3 bits)
BF: Broadcast Interpiconet flag (1 bit)
Size: Keeps the size of the RVF
RVF: Vector with a logical path if Size > 0
Properties

➢ Each Bluetooth Device has an unique UDP port which represents the MacAddr and the communication channel to send and receive the data.
➢ When the master is executed it will first search for a slave in inquiry state in a port range assigned in the configuration of the code.
➢ Master is always polling the slaves for information. If the master has data to send to a certain node it will send it to the slave in the polling packet.
➢ A slave can't send a message to a master unless the master has previously send a polling message to it.
➢ If the slave receives a polling message and has no data to return then it will return a Null Packet.
➢ Unicast and Broadcast Inter Piconet are posible if a slave is being shared in more than one piconet.
➢ If the master has data to send in its queue then it will give priority to that data before doing the normal ordered polling polling to the slaves.
**Deficiencies**

- The simulations has to be run in one computer. So the CPU and I/O performance is going to decrease with the increase of Bluetooth devices.
- The relays changes from piconet every time it receives a message from a master. It practically is simulating that it its hearding all the channels of the piconets it is connected. Also it doesn't spend any time in clock syncronization.
- The master detects when a Bluetooth Device has left a Piconet. But the master can't detect the presence of another Bluetooth Device on the fly.
- Improve the Bluetooth device memory utilization and add some limitations.
**Conclusion**

- Bluetooth is a very important and growing technology that will be useful in every Personal Area Network, because of its size and specifications it fits in almost every technological device or machine. It is the solution for cable replacement, even though it is not as cheap as it was intended to be. The specifications of Bluetooth leads to many limitations that make developers and algorithms creator to be very careful of them, and also causes that some algorithms implemented in different Wireless technologies cannot be applied, specially because of its limits in memory that leads to many others limitations. There is still work to do to improve its performance, efficiently use of memory, and piconets interconnection.