Design and Evaluation of a Common Access Point for Bluetooth, 802.11 and Wired LANs

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Abstract

Devices using wireless technologies like Bluetooth and 802.11b will be ubiquitous in the near future. The technologies supporting these devices will need to co-exist in order to support smooth exchange of information. We envision the existence of an Access Point (AP), that can support all these wireless technologies and bridge wireless networks with wired networks. We present the design and preliminary performance evaluation of two types of APs – a Bluetooth Access Point (BAP) and a Common Access Point (CAP) for Bluetooth, WLAN and Ethernet networks.

Keywords:*Bluetooth, Bluehoc, Access Point, L2CAP, Baseband, LMP, Congestion Avoidance, TCP, Piconet, 802.11*

1 Introduction

Present day wireless technologies range from short-range wireless technologies like Bluetooth[1] to long-range technologies like Satellite Wide Area Networks. With the increasing use of wireless devices, there are scenarios where these technologies may need to co-exist in order to allow different devices to exchange information with one another. In such scenarios, an Access Point provides a bridge between wired and wireless networks. For example, the base station(BS) in a WLAN is an Access Point between wired and the WLAN. We envision a need for a Common Access Point that supports different technologies - wired and wireless, and routes any kind of traffic. The Access Point will act as a BS, Bluetooth Access Point and might also have capability to transmit data over satellite.

In an effort towards developing a CAP as described in the previous paragraph, we implemented a Bluetooth Access Point to connect Bluetooth and wired networks, and extended it to support Bluetooth, wired and 802.11 networks. The wired network we considered is Ethernet. Observations on performance at the Access Points(CAP, BAP) developed in **Bluehoc**[3] simulator, an extension to **NS - 2**(version ns-2.1b7a)[2] are presented. Different ways of modeling an Access Point are discussed.

The rest of the paper is organized as follows. Section 2 briefly discusses **Bluehoc** simulator including its capabilities and limitations. Section 3 discusses different approaches of modeling a BAP. Section 4 provides the implementation details of the Access Points developed.In section 5 we describe our experimental setup and results.Finally section 6 summarizes and provides directions for future work.

2 The Bluehoc Simulator

Bluetooth[1] is a short range radio based wireless technology encompassing a simple low-cost, low-power, global radio system for integration into mobile devices. It facilitates wireless local networking in an ad hoc fashion among a wide variety of hand-held devices like Personal Digital Assistants (PDA), mobile PCs, Phones,pagers and headsets, desktops, notebook PCs, digital cameras, home appliances etc., forming a "piconet". Bluetooth devices detect, connect to and discover services from other devices in the vicinity without the user being aware of it. **Bluehoc** simulator is an extension to **NS-2** for evaluating performance issues in Bluetooth. In this section we briefly describe the **Bluehoc** simulator. The **Bluehoc** simulator models the different layers,- Bluetooth radio, Baseband, Link Manager Protocol(LMP) and Logical Link Control and Adaptation Protocol (L2CAP) of the Bluetooth protocol stack at varying degrees of abstraction. The Baseband supports functionalities like Frequency Hopping Kernel (79 hop), Error Model, Inquiry and Paging procedures, Transmission and reception of baseband packets, Interference from other piconets.

The various capabilities of **Bluehoc** simulator can be summarized as follows. The **Bluehoc** simulator can be currently used to perform the following studies

- Device discovery performance of Bluetooth
- Connection establishment and QoS negotiation
- Medium access control scheduling schemes
- Radio characteristics of Bluetooth system
- Statistical modeling of the indoor wireless channel
- Performance of TCP/IP based applications over Bluetooth

Bluehoc can be used to study performances in various scenarios as described above, but it has some limitations which can be summarized as follows.

- **Bluehoc** supports sending data from master to slave only. A slave in a piconet cannot send data to the master or to another slave.
- The piconets and scatternets are not dynamic in nature, i.e., a slave cannot join or leave an existing piconet.Within a piconet, a slave cannot switch into other modes like park or hold, as per the Bluetooth Specifications.
- **Bluehoc** does not support devices in low power modes, eg.,Sniff, Park.
- The scatternet version of **Bluehoc** does not support the scenario where a device is a master in one piconet and slave in another.

A new version that supports mobility and Ad hoc routing is due for release soon.

3 Bluetooth Access Point

Access Point for Bluetooth enables Bluetooth devices to access the Internet. Unlike other wireless technologies, Bluetooth has the concept of "piconet", consisting two kinds of devices. The device controlling the "piconet" is called the Master and the others are called Slaves. In this section we discuss Access Point as a master and slave. A Bluetooth piconet is synchronized by the clock of the master. The master keeps an exact interval of Mx625 microseconds (where M is an even, positive integer larger than 0) between consecutive transmissions. The slaves adapt their clocks with a timing offset in order to match the master clock. This offset is updated every time a packet is received from the master. Master always starts transmission in the even-numbered slots and slaves start in odd-numbered slots. Only the slave that is addressed by its AM_ADDR can return a packet in the following slot.

3.1 Bluetooth Access Point as Master

A BAP modeled as a Master of the piconet has the potential advantage of controlling the piconet and the devices that connect to it. The BAP in such a model does periodic inquiry and paging to discover new devices in its vicinity. When a device that wants to use the service of this BAP comes in into vicinity, it forms a piconet with BAP as the master. The BAP provides access to the Internet to all the slaves in its piconet as it has the routing information stored. Any slave in the piconet is only one hop away from the wired network in this model. The disadvantage of this approach being, according to the Bluetooth Specification, a piconet can have only seven active slaves at any given instant of time, hence the Access Point can at a time service seven devices.

3.2 Bluetooth Access Point as Slave

In a model where BAP is a slave, any device that connects to it to use the services of Access Point will become a master and forms a piconet. This can be visualized as formation of a scatternet with a slave belonging to more than one piconets. The routing can be done in a way similar to that of scatternet but there is a need to store routing information about the wired network to which it is connected. According to the Bluetooth Specification, there is no restriction as to how many piconets can a slave belong to. Theoretically, advantage of this approach is that any number of Bluetooth devices can connect as masters to the Access Point and use it. Issues related to interference and collision bound the number of devices connecting to the Access Point. Most of the hardware Access Points currently available in the market are modeled as slaves.

The two approaches discussed above have their advantages and disadvantages. The user patterns also may matter in the performance of the Access Points. For example, if the Access Point modeled as a Master sees that a particular slave in the piconet is not frequently using its service, that slave can be parked to free one of the seven slots. Similarly, the number of devices that connect as masters to the Access Point may depend on how fast can the Access Point switch the piconets. Presence of two masters that want to transmit data at the same instant might lead to contention at the Access Point.

4 Implementation

4.1 Bluetooth Access Point

The Access Point which acts as an interface for Bluetooth traffic and Ethernet traffic is made the master of the piconet. The Access Point is responsible for routing the Bluetooth piconet traffic and the

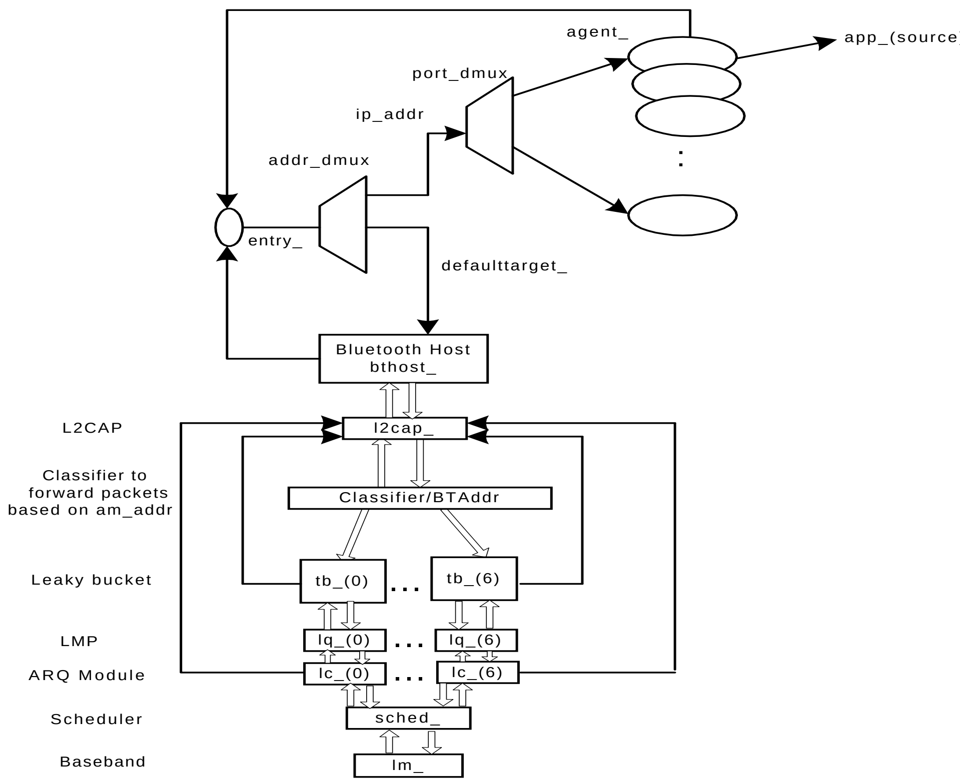


Figure 1. Structure of a Bluetooth Master

traffic generated by the piconet intended for the wired network similar to a BS in a 802.11 network. Implementation advantage being, only code at the master needs to be modified. The topology includes a link between the Access Point and the wired network.

As shown in Figure 1, the master node in the **Bluehoc** simulator has Bluetooth host, `bthost` as its `defaulttarget`, which is layered above the L2CAP layer. Whenever the master receives data, it hands over the data to the `bthost` layer, which in turn gives it to L2CAP layer.The L2CAP layer is responsible for the multiplexing of the data based on the `am_addr` of the slave.The `defaulttarget` of the Master, will no longer be `bthost` as it is acting both as an Access Point and Master in the piconet. The Access Point node has to route Ethernet traffic apart from the Bluetooth piconet. Only the Bluetooth traffic which is intended for the piconet should be handed over to the `bthost` and rest should be forwarded to the wired network. Once traffic is forwarded onto the wired network, the routing mechanisms that are already present in the wired network are responsible for routing of the packet to the appropriate destination on the wired network.

Bluehoc does not have the capability of sending data from a slave to master. It can only send data from master to slave and the ACKs are piggybacked along with the Baseband ACKS. Fixing this involved setting up L2CAP channels in the reverse direction after the LMP connections are setup.

Experiments with varying packet sizes and window sizes and durations were conducted, the results are described in the following section.

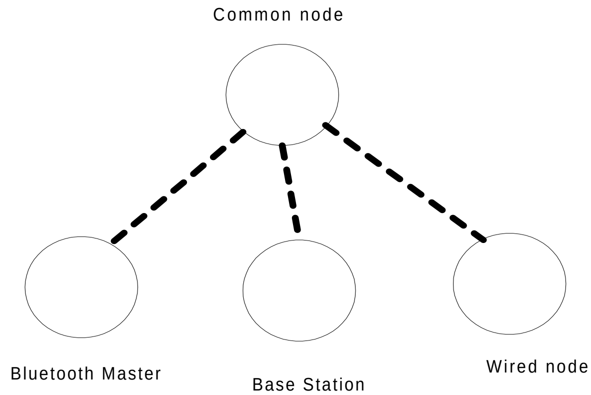


Figure 2. Access Point

4.2 Access Point for Bluetooth, 802.11 and Ethernet

Access Point that supports, Bluetooth, 802.11 and wired devices is designed as shown in the figure 2. This Access Point needs to act as a BS when it is serving 802.11 and wired devices and needs to serve as Bluetooth Access Point when serving Bluetooth and wired nodes. In addition to theses functionalities, it also need to route traffic between Bluetooth and 802.11 networks. The Access Point has the capabilities of Bluetooth Access Point and also BS. We assumed each of the networks viz., Bluetooth, 802.11 and Ethernet belong to different subnets. The Access Point consists of four components, a Bluetooth interface which acts as a Master, a 802.11 interface along with BS capabilities, a Ethernet interface and a Common node that routes traffic based on the subnet prefixes. The first three components give the data to Common node by default if not for their subnet. The Common node gives it to the appropriate interface depending on the subnet masks.We modeled and implemented a new node, Access Point in **NS-2** with the four components described above. The performance achieved was comparable to that of BAP.

5 Experimental Setup and Results

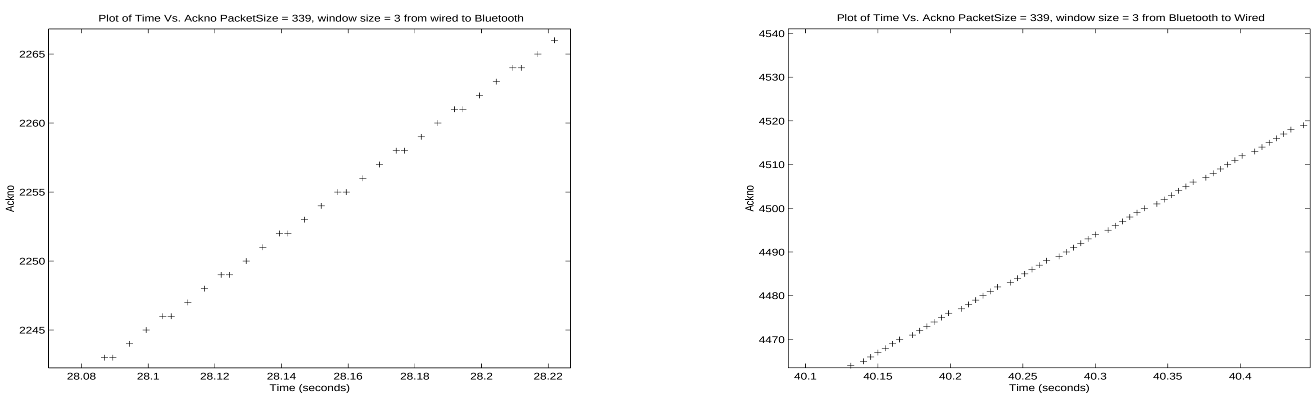
The experimental setup for BAP included, the BAP routing traffic between Bluetooth piconet with one slave and a wired node. TCP traffic was transmitted from Bluetooth slave to wired node and vice versa. Experiments were conducted by varying the number of slaves from one to seven. The number of nodes in the wired network was varied correspondingly from one to twenty nodes with different topologies. To test the correctness of BAP, experiments with more than one traffic source attached to each node were also performed.

The experimental scenarios for testing CAP were modeled on similar lines. The basic scenario consisting of making the CAP route traffic between a Bluetooth slave, an 802.11 node and a wired node was tested. Testing included transmitting TCP traffic between all possible pairs and also attaching more than one traffic source at each node. The number of nodes in Bluetooth piconet were varied from one to seven and those on the Ethernet and 802.11 were varied from one to twenty. Experiments were also conducted by varying the TCP window size and packet sizes. The table1 shows the comparison of the throughputs obtained when CAP and BAP were used. Experiments were carried out to test for TCP fairness varying the number of slaves.

The TCP fairness observed when experiments were conducted using Common Access Point and compared with the results obtained from 802.11 network. The parameters of the TCP used were a packetsize of

src	sink	Throughput(BAP) (pkts/sec)	Thoughput(CAP) pkts/sec	window size
BT	Wired	66.65	53.32	1
Wired	BT	66.608	53.32	1
BT	Wired	76.13	78.6	2
Wired	BT	66.60	72.72	2
BT	Wired	76.13	78.6	4
Wired	BT	66.60	72.8	4
BT	Wired	76.13	78.6	8
Wired	BT	66.60	72.96	8
BT	Wired	76.13	78.6	16
Wired	BT	66.608	73.28	16
BT	Wired	76.13	78.6	32
Wired	BT	66.60	73.96	32

Table 1. Throughputs obtained when using CAP and BAP



(a) (b)

Figure 3. Time Vs. Ackno graph for window=3 using BAP packetsize=330(a) from Wired to BT (b) from BT to Wired

number of slaves	direction	slave1/ device1	slave2/ device2	slave3/ device3	slave4/ device4	slave5/ device5
1	BT-Wired	78.6	-	-	-	-
1	Wired-BT	72.68	-	-	-	-
2	BT-Wired	26.88	53.04	-	-	-
2	Wired-BT	29.32	52.16	-	-	-
3	BT-Wired	33.48	27.06	50.06	-	-
3	Wired-BT	32.04	17.32	30.68	-	-
4	BT-Wired	16.24	28.26	30.24	22.04	-
4	Wired-BT	15.68	28.2	28.04	7.8	-
5	BT-Wired	18.32	20.4	8.84	9.52	15.24
5	Wired-BT	12.76	22.36	20.56	2.96	16.04

Table 2. Comparison throughputs (pkts/sec)TCP Fairness for Bluetooth

number of nodes	direction	type of network	slave1/ device1	slave2/ device2	slave3/ device3	slave4/ device4	slave5/ device5
1	802.11-Wired	802.11	159.68	-	-	-	-
1	Wired-802.11	802.11	159.68	-	-	-	-
2	802.11-802.11	802.11	81.72	77.08	-	-	-
2	Wired-802.11	802.11	78.12	81.32	-	-	-
3	802.11-Wired	802.11	39.72	84.84	37.2	-	-
3	Wired-802.11	802.11	58.6	56.68	44.36	-	-
4	802.11-Wired	802.11	36.28	83.4	38.04	4.24	-
4	Wired-802.11	802.11	19.84	36.92	34.36	68.4	-
5	802.11-Wired	802.11	5.92	61.64	60.4	61.64	20.16
5	Wired-802.11	802.11	5.92	61.64	60.4	61.64	20.04

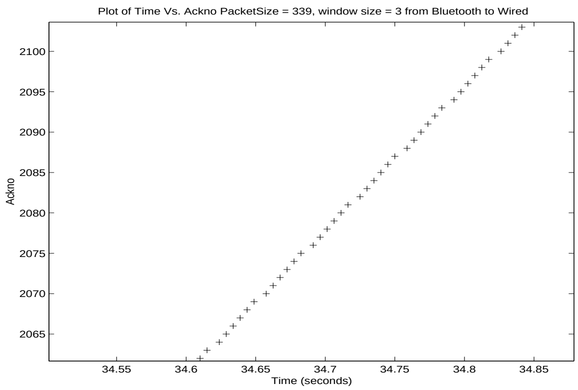
Table 3. Throughput (pkts/sec) for 802.11 networks

1000 bytes and window size equal to 20 packets.The results of which are given in Table 2 and Table 3. From the table it is evident that there is asymmetry internal to the piconet, i.e., when more than one slave is sending data, the throughputs of the slaves differ. This kind of internal TCP asymmetry is observed even in the case of 802.11 networks.

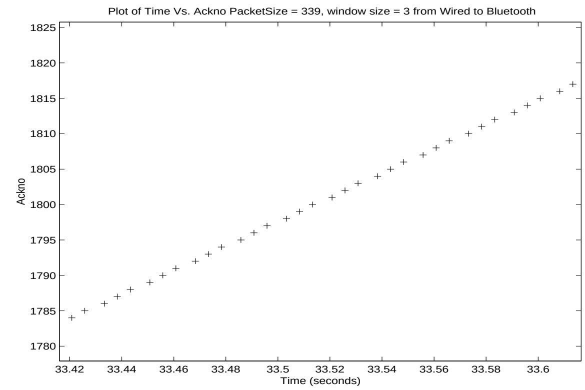
The results of the tables show that the throughputs obtained from an 802.11 network is high when compared to those obtained from Bluetooth. The reason for this could be the TCP of slave is resorting to congestion avoidance when transmitting data. However asymmetry in the throughputs is observed in both the cases.

The graphs[1] show the plots of the ACK no Vs Time when CAP and BAP were used. From the graphs Linear behavior and comparable performances are observed in both the cases.

[1]**Note:** Only partial graphs are shown to clearly show the difference between the two scenarios



(a)



(b)

Figure 4. Time Vs. Ackno graph for window=3 using CAP packetsize=330 (a) from BT to Wired (b) from Wired to BT

6 Conclusion and Future work

An Access Point may be modeled as a Slave in the piconet and the performances compared. There are other issues like interference and collision that need to be investigated. The Access Point can be made to have QoS capabilities so that it regulates the bandwidth in different type of networks and perform optimized scheduling depending on the bandwidth available.

The future work also involves enhancing **Bluehoc** in the following ways.

- Incorporating mobility and Ad-Hoc Routing into the scatternets
- Implementing SCO links
- Making the piconets and scatternets dynamic,this can viewed in two ways
  - slave moving in and out of piconet
  - slave on/off within the piconet
- Investigating the low power modes like **Sniff**, **Park**
- Allow the current scatternet version the master in one piconet slave in other. Mechanism is needed for Master/Slave switch

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