Scatternet Structure for Improving Routing and Communication Performance

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INTRODUCTION

As a new promising short-range wireless technology, Bluetooth (Bluetooth; Bray & Sturman, 2001; Miller & Bisdikian, 2000) is designed to enable voice and data communication among various devices. It has received great attention in recent years. Bluetooth SIG develops Bluetooth specifications. By using the unlicensed 2.4 GHz ISM band, Bluetooth devices can communicate within a local area, intended as a replacement of interconnect cable. It supports connection-oriented and connectionless links and thus is suitable for both voice and data communications. The characteristics of low cost and low energy consumption make it not only the ideal technology for wireless local area network but also the best candidate for wireless personal area network (Haartsen, 1998).

When two Bluetooth devices communicate with each other, they must set up a link at first. One device acts as master and the other acts as slave. Actually, Bluetooth specifications can support up to seven slaves for one master. The mini-network constructed by one master and several slaves is called piconet.

Limited to the communication range and slave number, usually, a single piconet is not enough for actual usage. Also, if we permit Bluetooth devices in the same short range to communicate freely, they will influence each other and lower down the whole performance. Fortunately, one Bluetooth device can act as slave in several piconets and master in one piconet simultaneously. Such Bluetooth devices, existing in several piconets, are called relay. Through relay, several piconets can connect and form a scatternet. Scatternet not only provides larger range communication, but also regulates Bluetooth devices' actions to improve the whole performance.

To construct a scatternet, the structure and routing are two major issues. The scatternet structure deals with automated procedures to select master and slaves in a piconet and relays between piconets, and the topologic structure of scatternet to improve scatternet performance. The routing algorithm deals with delivery of messages in such a scatternet (Sairam, Gunasekaran, & Redd, 2002).

Many scatternet structures and routing algorithms have been proposed in recent years. The following paragraphs will analyze three scatternet structures. After that, we present a new topologic structure, named SolidRing, with its routing algorithm. Finally, there are some discussions on SolidRing's performance.

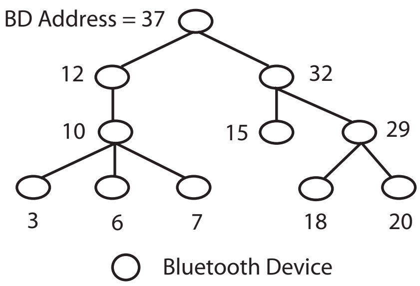
BACKGROUND

Usually, when designing scatternet, the two issues, structure and routing algorithm, can't be divided absolutely, and influence each other. With a suitable routing algorithm, scatternet performance would be remarkably improved. Of course, to different structures, the meaning of "suitable" is very different. Also, a specific routing algorithm can only be realized in some structures (Prabhu & Chockalingam, 2002; Bhagwat & Segall, 1999; Shih, Wang, & Su, 2003). In a scatternet, the two should be designed appropriate to each other.

In recent papers of scatternet, various structures and routing algorithms are proposed. After studying the papers, two basic routing algorithms and three basic structures can be concluded.

Generally, basic routing algorithms are: proactive and reactive (Royer & Toh, 1999). Reactive routing algorithms find routes only when needed, while proactive algorithms maintain valid routes all the time. So, proactive consumes more energy and memory to win time while reactive contrary. Since Bluetooth initially was designed as a low price and low energy technology, a small Bluetooth device can't accommodate the large table and power consumption needed for proactive. Reactive is not an advisable choice as well. Because Bluetooth can only communicate through comparatively narrow master-slave links, routing data flow and long waiting time can't be tolerant. For our new structure, SolidRing,

Figure 1. Tree structure



we will present a new routing algorithm, a combination of the two. The routing algorithm is simple and fast, but it can only execute in SolidRing for the structure has some special characteristics (Kim, Lai, & Arora, 2003).

THREE STRUCTURES

For scatternet structure, there are three basic types: tree structure, planar structure and ring structure. Each structure has its own merits and demerits.

Tree Structure

The topologic link of tree structure is shown as Figure 1. The merit of tree structure is a very simple routing algorithm, just as described in Sun, Chang, & Lai (2002). The structure is constructed to be regular according to BD Address (Bluetooth Device Address). Root node is max BD Address device of the scatternet. Its sub-trees have different BD Address ranges, for example, the 1st sub-tree has the range of 100-200, the 2nd sub-tree has the range of 200-500, the 3rd sub-tree has the range of 500-700, and so on. BD Address ranges of sub-trees will not overlap each other. Following the rule, each node has several sub-trees whose BD Address ranges don't overlap. And, each node keeps information about its sub-trees BD Address range.

When a node tries to communicate with another node, it will compare the destination BD Address with its record of BD Address ranges of its sub-tree. If the destination BD Address is out of the range, it will pass a routing message to its father node. Otherwise, it will pass a routing message to the corresponding sub-tree. Each node that accepts the routing message, will act like this. Following the algorithm, the message will arrive at the destination. Then, the message will send back and the routing work finished.

By analyzing the routing algorithm clearly, we can find that the routing message is directly passed from start node to destination node without any unnecessary message. It's a very efficient routing algorithm and should owe to the regular formation. Routing work is sharply reduced. While the structure has an excellent routing performance, its demerits are critical.

The first problem is serious bottleneck. The structure looks like a pyramid. From bottom to top, the paths become less and less. Even on the top of the pyramid, all communications must pass through root node of the tree. Obviously, it will result in serious bottleneck. The following will give some mathematic calculations to show the bottleneck problem.

Assuming there is a b-branch, n-layer tree and all nodes in the tree communicate with each other once. From root node, the tree can be divided to number of b sub-tree, that each one is a branch with its own sub nodes. The communications related to a sub-tree include two parts: internal and external communications. Internal means the sub-tree nodes communicate with each other. External means the sub-tree nodes communicate with nodes that don't belong to the sub-tree. Then, for the sub-tree, the communications that must pass through root node are just the external communications. The total nodes number is N, and a sub-tree nodes number is B. Then, we can calculate the percent of communications passing through root node.

The total nodes number

$$N = b^n - 1 \tag{1}$$

A sub-tree nodes number

$$B = b^{n-1} - 1 \tag{2}$$

Sum of communications of assumption

$$P_N^2 \tag{3}$$

Total communications for a sub-tree

$$B(N - 1) \tag{4}$$

Internal communications

$$P_B^2 \tag{5}$$

Then, percent of communications passing through root node is

$$b \times \frac{B(N-1) - P_B^2}{P_N^2} \times 100\% \tag{6}$$

According to the equation (6), we can calculate that 66.7% communications have to pass root node for 3-branch, 5-layer tree and 51.6% communications for 2-branch, 5-layer tree. That means most of communications must pass through root node. In such situation, root node is very easy to be blocked and bottleneck problem is very serious.