行政院國家科學委員會專題研究計畫　成果報告

子計劃四：無線行動隨意網路上之移動支援與電源管理協定（I）

計畫類別：整合型計畫
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計畫主持人：張明峰
共同主持人：曾煜棋

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行政院國家科學委員會補助專題研究計畫成果報告

多階層行動隨意網路之設計及實作 子計畫四：無線行動隨意網路上之移動支援與電源管理協定 Design & Implement Location-Aware of Mobile Ad Hoc Networks Sub-Project(2): Location-Aware Routing Protocols for Mobile Ad Hoc Networks

計畫類別：□個別型計畫　　■ 整合型計畫
計畫編號：NSC 91－2219－E－009－006－
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成果報告類型(依經費核定清單規定繳交)：■精簡報告　□完整報告

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摘要：

本計劃主要解決在多階層行動隨意網路中所須面臨的問題。我們定出兩大研究方向。第一，為了達到多系統整合與漫遊的目的，將在建置的具多步跳耀通訊子網路上提出解決多階行動隨意網路 Mobile IP 之設計與實作，以解決與其他多階系統 GPRS，Bluetooth 整合的問題。另外，亦將針對在 WiFi 與 Bluetooth 並存時所衍生的問題，如為了降低干擾，從頻道之選擇與封包之切割，提出有效解決對策。

關鍵字：多階行動隨意網路，行動管理，電源管理。

Abstract

In this project, we solve the problems occurring in multi-tier mobile ad hoc network. We focus on the two research topics. First, in order to integrate the system we design and implement and roaming between systems. We design multi-tier mobile ad hoc network mobile IP for multi-hop ad hoc network to solve the problem of multi system integration, e.g. GPRS and Bluetooth. And then, we focus on the problem of interference when WiFi and Bluetooth coexist by choosing better channel or designing packets format.

Keywords: multi-tier mobile ad hoc network, mobility management, power management.

1 Introduction

Wireless communications and mobile computing are gaining more popularity in recent years. Wireless communication devices have become standard features in most portable computing devices, such as laptops, PDAs, and handsets. People are becoming used to carrying computers while traveling around to enjoy the tremendous services on the Internet. Ubiquitous computing has added a new feature, mobility, to the world of computing and communications.

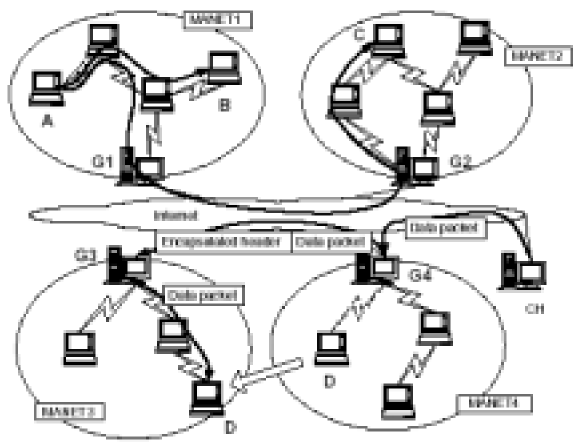
We have observed two strong growths of interests related to this trend. The first one is Mobile IP, which supports mobile hosts roaming from subnet to subnet without need of changing IP addresses. Mobile (home and foreign) agents are used to support seamless handoffs. The next generation IPv6 will include features of Mobile IP as inherent functionality. Another emerging wireless network architecture is the mobile ad hoc network (MANET), which can be flexibly and conveniently deployed in almost any environment without the need of infrastructure base stations. MANETs have received intensive attentions recently. In the literature, most works are based on IEEE 802.11-like network interface cards to build a MANET. The recently proposed wireless sensor networks also have a similar architecture to the ad hoc networks.

Another issue we want to solve is in a multi-Bluetooth picocells environment. As a promising WPAN technology, Bluetooth is expected to be used in many applications, such as wireless earphones, keyboards, wireless access points, etc. Operating in the unlicensed 2.4GHz ISM band, multiple Bluetooth piconets are likely to coexist in a physical environment. With a frequency-hopping radio and without coordination among piconets, transmissions from different piconets will inevitably encounter the collision problem. In a previous work, the author investigates the co-channel interference between Bluetooth piconets and derives an upper bound on packet error rate. The analysis has two limitations. First, all packets are assumed to be single-slot ones. Second, it is assumed that each piconet is fully loaded, in the sense that packets are sent in a back-to-back manner. These constraints greatly limit the applicability of the result.

2 **Network architecture and communication scenarios**

A. Network model

We consider the network consisting of multiple MANETs, each of which has a point of attachment to the backbone Internet. The host connecting a MANET to the Internet is called the gateway. We use gateways to define the ranges of MANETs. Each gateway has two network interface cards, one wireless and one wireline. Gateway hosts have no mobility since they have fixed links. However, non-gateway hosts can roam around freely, and thus the definition of MANETs actually changes by time. Gateways are responsible of intertworking MANETs with the Internet by forwarding/relaying packets. To support Mobile IP, each gateway also serves as the FA in its local MANET. So it should periodically broadcast AGENT_ADVERTISEMENT messages to announce its service to members of its MANET. Since members of MANETs are mobile, it is likely that a MANET is partitioned into multiple MANETs, or some MANETs may join and overlap with each other. In such cases, the boundaries between MANETs become vague, making the service ranges of FAs unclear. We propose to define the service ranges of gateways by associating with each gateway a parameter N. Any mobile host within N wireless hops from the gateway can join the MANET served by the gateway. This is achieved by specifying a TTL = N in each gateway's AGENT_ADVERTISEMENT. For example, host A, though connected to MANET2, cannot be a part of the network. In case that a host is within the service ranges of multiple gateways, it can choose the shortest-distance one as its default gateway. By so doing, the boundaries of subnets are clearly defined even if MANETs are overlapping with each another. For example, host C belongs to MANET3, while host B belongs to MANET4, and their HAs will tunnel IP datagrams accordingly from the proper gateways. Also, note that each gateway can define its own N independently based on its willingness/capability to provide services. When MHs move around, it is even possible that a MH is disconnected from its gateway, but still remains connected to other MANETs. For instance, if the link between G3 and D breaks, hosts D's and E's connections to the Internet will become broken because they are beyond the service range of G4. To dynamically adjust a gateway's service range, we propose that a MH, on missing AGENT_ADVERTISEMENT for a certain period, may broadcast or multicast an AGENT_SOLICITATION message with a TTL = N'. The value of N' can be gradually increased to avoid the broadcast storm problem caused by flooding. The solicitation can be heard if N' ≧ N and the MANET is connected. On receiving the AGENT_SOLICITATION, the gateway may decide, based on its willingness, whether to increase its N or not. In the above example, if host E's AGENT_SOLICITATION has an N' = 5, G4 will receive the request, and may increase its service range to cover D and E.



B. Some communication scenarios

Based on the above network architecture, several different communication scenarios may exist. In the following, we discuss the possible combinations and the corresponding routings. In the discussion, we assume that routing in MANETs is supported by DSDV (however, any proper routing protocol for MANETs is applicable).

- Intra-MANET communication: The communications are supported by DSDV. In the DSDV protocol, hosts will exchange routing information periodically and compute the next hop to reach the destination with the least metric (such as hop count). Proper route entries will be written into the kernel routing table by system calls. So whenever a route entry leading to the destination is found, the packet is directly forwarded to the next hop.
- Inter-MANET communication (direct): For any packet whose destination is not listed in the kernel routing table, it will be forwarded to the gateway of the local MANET. The gateway will then forward the packet to the Internet.
- Inter-MANET communication (with Mobile IP): A MH may roam away from its home network. In this case, Mobile IP will be involved to forward packets between MANETs. To support such scenario, MHs have to monitor any existing AGENT_ADVERTISEMENT. Registration and deregistration procedures in Mobile IP should be followed. The routing of these packets will be supported by DSDV. HAs should maintain the current locations of its MHs. FAs should maintain the visiting MHs in their MANETs. HAs should execute proxy ARP for roaming MHs.
- Inter-MANET communication in overlaid MANETs (direct): When two MANETs overlay with each other, a MH may be aware of a route to another MH that belongs to a neighboring MANET. This is made possible by the frequent exchange of routing information by DSDV. In this case, directly routing between these MANETs is allowed. To support such scenario, we propose to associate with DSDV a parameter M, which reflects the service range of DSDV. I.e., a MH always collects/propagates routing information for MHs that are within M wireless hops from itself. As a result, hosts in different, but connected, MANETs may communicate with each other directly. The routing, tunneling, and encapsulating overheads can be reduced by such optimization. Note that it is mandatory that $M \geqq N$ so that routing information leading to the local gateway is always known by a MH.
- Inter-MANET communication in overlaid MANETs (with Mobile IP): Contrary to the above scenario, when two MHs are resident in connected MANETs but away by more than M hops, their communications should be routed through the Internet. As can be expected, the values of N and M should be properly tuned to reduce overheads and improve efficiency, which may be directed to an interesting research problem.
- Broadcast: Broadcasting is useful in many circumstances. In wireline communication, the scope of broadcast is well defined a broadcast message is typically flooded to the physical range covered by a subnet. In wireless communication, due to the radio transmission property, the range that should be covered by a broadcast is usually not well defined. This is particularly true for ad hoc networks, where each MH has its own radio coverage. Note that if we directly adopt a TTL value to a broadcast packet, each

mobile host's broadcast range will be distinct (depending on its current location). We propose to define the coverage range of a broadcast as the service range provided by the local gateway where the broadcast is issued. As a result, the range of a subnet matches with the range of a MANET. The detailed routing is conducted as follows. When a MH wants to send a broadcast datagram, it first encapsulates the packet as a unicast by identifying the gateway as the destination host. When the unicast packet is tunneled to the gateway, the gateway will decapsulate the packet and find that it is a broadcast packet. Then the gateway broadcasts this packet on behalf of the original source with a TTL = N.

3 Collision analysis in a multi-piconet environment

Another issue we want to solve is collision analysis in a multi-piconet Bluetooth environment. Let's consider a piconet X and another competitor piconet Y, which is regarded as the unique source of interference to X. With the interference from Y, we first derive the success probability Ps(i) of i-slot packets in X, where i=1, 3,5. We start by introducing the concept of ``slot delimiter." Consider any slot in X. One or two slot delimiters in Y may cross X's slot. However, since we are considering continuous probability, the possibility of two crossing slot delimiters can be ignored, and thus we will deal with one crossing delimiter in the rest of the discussion. For example, for a 1-slot packet in X, it succeeds only if there is no interference from the two slots before and after the delimiter, so the success probability of X's packet could be 1,(78/79), or$(78/79)^2$, depending on whether Y transmits or not. Below, we denote the constant factor 78/79 by P_0. Next, we further elaborate on slot delimiters. Depending on what packet(s) is divided by it, a delimiter is classified into ten types.

- B_1, B_2, B_5: the beginning of a 1-, 3-, and 5-slot packet, respectively.
- B_3, B_4: the beginnings of the second and third slots of a 3-slot packet, respectively.
- B_6, B_7, B_8, B_9: the beginnings of the second, third, fourth, and fifth slots of a 5-slot packet, respectively.
- B_{10}: the beginning of a dummy slot.

It is easy to see that the rate of B_1 is λ_1 per slot; the rate of each of B_2, B_3, and B_4 is λ_3; the rate of each of B_5, B_6, B_7, B_8, and B_9 is λ_5; and the rate of B_{10} isλ_0. For ease of presentation, we denote the arrival rate of B_j by $\lambda(B_j)$, j=1..10. Given any B_j, we also define g(j) to be the number of slots that follows delimiter B_j and belong to the same packet.

Definition 1: Given any i-slot packet in piconet X and any interference source piconet Y, define L(k), k < i, to be the probability that the packet of X experiences no interference from Y starting from the delimiter of Y crossing the (i-k+1)-th slot of the packet to the end of the packet, under the condition that the aforementioned delimiter is of type $B_1/B_2/B_5/B_{10}$. For k ≦ 0 ,L(k) = 1.

Intuitively, L(k) is the success probability of the last k slots of X's packet excluding the part before the first delimiter of Y crossing these k slots, given the delimiter type constraint. With this definition, we can find Ps(i) by repeatedly cutting off some slots from the head of X's packet, until there is no remaining slot. Specifically, we establish Ps(i) by L( ) as follows:

$$P_S(i) = \sum_{j=1}^{10} \lambda(B_j) \cdot f(j) \cdot L(i - g(j))$$

where

$$f(j) = \begin{cases} (1-\lambda_0) \cdot P_0^2 + \lambda_0 \cdot P_0 & \text{if } j = 1,2,5 \\ (1-\lambda_0) \cdot P_0 + \lambda_0 & \text{if } j = 10 \\ P_0 & \text{otherwise} \end{cases}$$

4 Conclusions

We have investigated the related issues to integrate MANETs with Mobile IP. Hence, traditional access points can directly enjoy the flexibility of MANETs and widen their coverage ranges. In view of the worldwide explosive deployments of IEEE 802.11-based access points, such extension would help make our dream of ubiquitous broadband wireless access come true. Details of our prototyping and implementation experiences are reported. In addition, we analysis the collision problem in multi-picocells Bluetooth environment and obtain better performance.

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