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Influence of Roaming on Real-Time Traffic in Wireless Networks

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Abstract **- This paper briefly presents an ongoing work on the roaming techniques used in wireless LANs and their impact on real-time services. Both 802.11 and Bluetooth are considered but only 802.11 offers a standardized support of mobility, which can be implemented in different ways.**

In the future, we want to design and implement a software layer above the existing Medium Access Control, which would allow real-time traffic to be guaranteed over standard wireless network adapters.

This study will help in identifying and evaluating the implications of roaming and its impact on the quality of real-time services.

I. INTRODUCTION

Wireless technologies offer the user the possibility to move while being able to communicate with the wired network infrastructure. This is considered as a useful feature but it is implemented in different ways with different capabilities, in terms of functionality as well as in terms of quality. Moreover, roaming techniques introduce a noticeable overhead and disturb the expected behavior of the network, leading to potential transmission delays or errors. Furthermore, the number of "hops" (or cells) and wired segments that the data must go through will impact on the end-to-end delays.

Our study is focusing on two wireless technologies: 802.11, which presents some interesting roaming options, and Bluetooth, which does not include any specific roaming capabilities.

The final objective of this study is to define real-time services based on the above mentioned wireless technologies, without modifying the underlying Medium Access Control nor the roaming/handover techniques. Roaming is therefore of great concern for the designers and implementers of such services.

II. PRESENTATION OF WIRELESS LANS

A. IEEE 802.11

IEEE 802.11 [2] is a digital wireless data transmission standard in the 2.4 GHz ISM band aimed at providing a wireless LAN between portable computers and between portable computers and a fixed network infrastructure. This standard is defined up to the MAC layer. The air interface physical layer of 802.11 can be of three different types: infrared, frequency hopping and direct sequence spread spectrum. The most popular technology is the direct sequence spread spectrum and can offer a bit rate of up to 11 Mbps in the 2.4 GHz band, and, in the future, up to 54 Mbps in the 5 GHz band

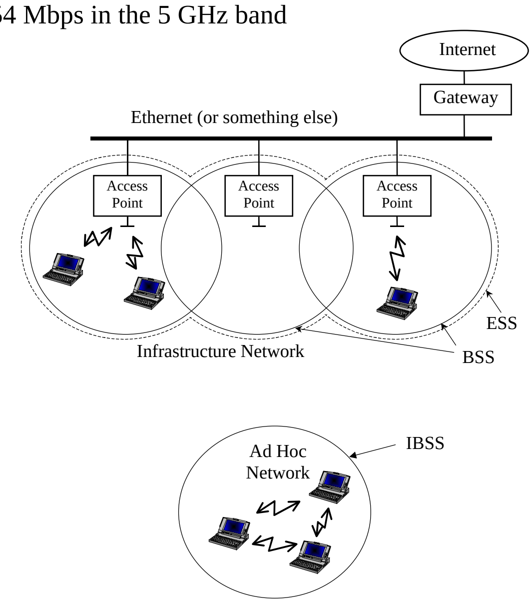

Figure 1. 802.11 Infrastructure or Ad Hoc network

A 802.11 node is either operating in an infrastructure network or in an ad hoc network (see Figure 1). In an infrastructure network, all traffic is going through the access point, even if the destination computer is in the same cell. A so-called distribution system takes care of the packet forwarding towards the destination computer across the wired network infrastructure. In Ad Hoc mode, every computer can directly communicate with every other computer inside the cell, exactly as on an Ethernet cable. There are different channel frequencies to choose from. In an infrastructure network, neighbor access points are assigned different frequencies. Each access point is transmitting a beacon in its frequency so that the laptops can find it. In an Ad Hoc cell, all laptops must use a predefined frequency.

B. Bluetooth

Bluetooth [1] is a digital wireless data transmission standard in the 2.4 GHz ISM band aimed at providing a short range wireless link between laptops, cellular phones and other devices. The air interface raw data rate is of 1 Mbps.

Two types of links are defined: the Synchronous Connection-Oriented (SCO) link, where slots are reserved for packets, and the Asynchronous Connection-Less (ACL) link. For each channel, different levels of forward error correction are defined. The synchronous link with 1/3 coding rate (HV1) can carry 10 bytes per packet. As a time slot is 625 ms long, if such a packet is sent every two time slots then the user bit rate will be of 64 kbps. A synchronous packet HV3, i.e. without forward error correction, can carry 30 bytes and a 64 kbps channel uses one time slot every 6 slots. The asynchronous link can support a maximal asymmetric data rate of 723.2 kb/s (and 57.6 kb/s in the return direction), or a symmetric data rate of 433.9 kb/s.

Two or more units sharing the same channel, i.e. the same frequency hoping sequence, form a piconet. A Bluetooth piconet is composed of 1 master and of up to 7 slaves. A master can support up to three SCO links with one or several slaves. A slave can support SCO links with different masters at the same time, but only 1 SCO link with each of them. A maximum of one ACL link can be opened between a master and a slave.

Overlapping piconets form a scatternet. A slave can be slave of the masters of two different piconets. Piconets are not synchronized. Any master can, if it has spare time, be the slave of another master. If an ACL link is opened in piconet 1, the node must enter the hold or park mode in piconet 1 during the time it visits piconet 2. Units in sniff mode can visit the other piconet in between the sniff slots. If an SCO link is opened, things get more difficult: On an HV1 SCO link, packets are sent every two slots, occupying the whole capacity. On an HV2 SCO link, packets are sent every 4 slots, occupying half of the capacity. On an HV3 SCO link (i.e. without forward error correction), packets are sent every 6 slots. Because the piconets are not synchronized, it is only possible to visit another piconet if an HV3 SCO link is opened: From the 4 slots between two HV3 packets, two slots cannot be used because of the time overlap with the slots in the other piconet, leaving only two slots to be used to visit the other piconet.

Bluetooth for wireless local area networks

The two solutions to use Bluetooth as a mean to interconnect equipment that are further away from one another than the range of a piconet is to use either Bluetooth as an wireless access to a wired infrastructure network or to form a multi-hop wireless network.

The main limitation of Bluetooth regarding the requirements of the air interface for a wireless multi-hop network is that its network topology is basically limited to the point-to-multipoint structure. Different point-to-multipoint piconets can be linked together through nodes participating alternatively in two different piconets. These nodes can relay asynchronous and, under sever limitations, synchronous data traffic between piconets: If an asynchronous link is opened in piconet 1, the node must go into a reduced activity mode during the time where it visits piconet 2. If a synchronous link is opened in piconet 1, the node can only visit piconet 2 in between the slots reserved for the synchronous link. A master of a piconet under heavy load wills only difficulty find some spare time to visit another piconet as a slave. A router between two piconets should hence most probably have two Bluetooth hardware interfaces in order not to be a traffic bottleneck. To implement a wireless multi-hop packet network over Bluetooth, a packet routing layer remains to be defined above the LLC layer of Bluetooth. To implement a wireless multi-hop circuit network using Bluetooth, a circuit setup protocol should be defined to open circuit across several nodes. In the intermediate nodes, a circuit switch function must also be defined to forward the traffic between the LLC layers of each interface.

Several service profiles define how the Bluetooth link and physical layers shall be used by Bluetooth enabled devices. These profiles allow the interoperability of devices from different manufacturers up to the application. All profiles define end-to-end services: cordless telephony, intercom, serial port, headset, dial-up, fax, LAN access, generic object exchange, object push, file transfer, synchronization. The LAN access profile, which uses the PPP protocol, is hence the current standard way to access an infrastructure network.

III. IMPLEMENTATION OPTIONS FOR THE DISTRIBUTION SYSTEM IN 802.11[1]

A. Network Architecture

The wireless LAN standard IEEE 802.11 defines two basic modes of operation: the *infrastructure* network and the *ad hoc* network (see Figure 1). The infrastructure network is meant to extend the range of the wired LAN to wireless cells, which form a virtual single shared-medium. A laptop can move from cell to cell while keeping access to the resources on the wired LAN. A cell is the area covered by an access point and is called a *basic service set* (BSS). The collection of all cells of an infrastructure network is called an *extended service set* (ESS).

The ad hoc network mode is meant to easily interconnect laptops that are in the same area, for example in a meeting room. No access to a wired LAN is foreseen. The interconnected stations in ad hoc mode are forming an *independent basic service set* (IBSS).

An Access Point (AP) connects the Distribution System (DS) to the Basic Service Set, whereas a Portal connects the Distribution System to the Wired LAN. The Access Point and the portal form a MAC bridge between the wired LAN and the cells (figure 2).

[1] This subject is fully covered in [7]

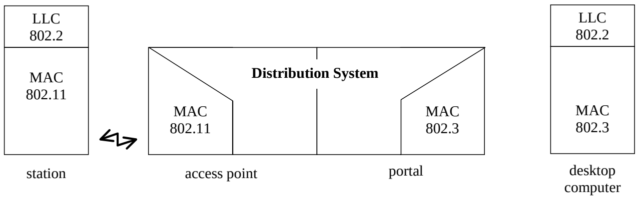

Figure 2. 802.11-LAN MAC bridge

The Distribution System is transparent to the LLC and it is responsible for routing frames.

B. Roaming

The association protocol gives to the distribution system the necessary information to manage mobility. The operations of a moving station in an 802.11 infrastructure network are briefly presented in Figure 3:

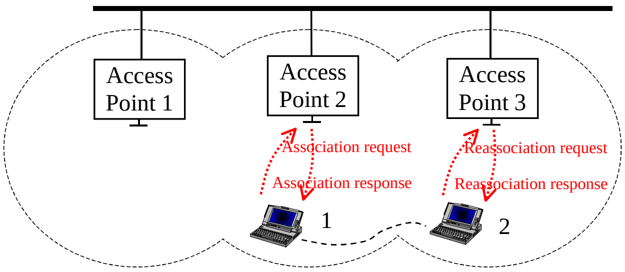

Figure 3. 802.11 roaming principle

A. Scanning: When a station powers up inside the coverage area of an access point, it listens for a beacon frame containing the identity (SSID) of the wireless network that the station wishes to join.

B. Association: The station sends an association request to the access point, informing the access point (AP) of its presence and of its MAC address.

C. Traffic: Station 1 sends a message to station 2 through the AP 2, which, as an example, looks into its table to find out by which AP station 2 is covered, and then forwards the message to AP 3. AP 3 sends the message to station 2. If station 1 and 2 were in the same BSS, the scheme would be identical: the message would be received by the AP and forwarded to station 2. There is no direct traffic between two wireless stations.

D. Mobility: When station 1 moves from BSS2 to BSS3, it sends a reassociation message which contains its MAC address and the identity of the old access point.

E. Disassociation: When leaving the network (e.g. when shutting down), the station should send a disassociation message to the access point. This message shall not be mandatory for the system to work.

C. Implementation of the Distribution System

Two possibilities to implement the distribution system are presented hereafter. The first one uses a MAC layer addressing and the second one a network layer addressing.

The problem can be divided into two parts. The first is to choose how to transport the data across the distribution medium. The second is to choose a signaling protocol between access points and the portal to keep the local routing tables up-to-date.

D. Roaming using bridging access points

The maximal frame body size of 802.11 Frames as defined by the standard is 2312. If this number can be reduced to 1500 to be compatible with 802.3 Ethernet, the access point can bridge the traffic between the wireless cell and the wired LAN as shown in Figure 4. In order not to overload the cell with wired traffic, the access point will only bridge into the cell the traffic for MAC address that are known to be in the cell. The knowledge of which MAC address to filter is gained through the association messages received from the stations.

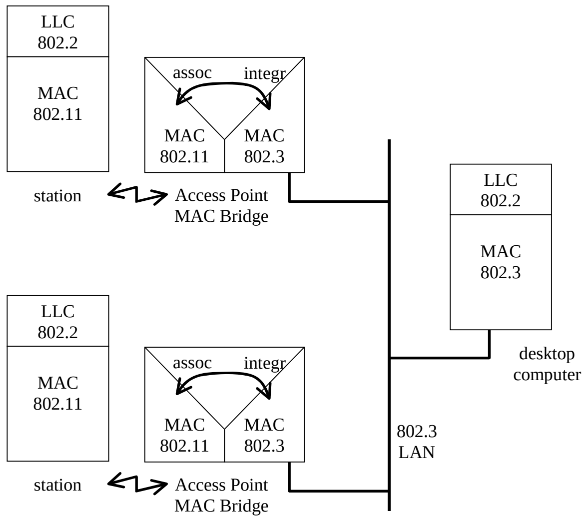

Figure 4. Separated Access Points and Portals

E. Roaming using network layer addressing and a centralized dynamic route resolution protocol

Having all access points connected to the same medium as needed for the bridging solution limits the flexibility in the deployment of the access points. It is possible to use a network layer addressing between the access points using the stacks shown in Figure 5. This will permit to run the location management and forwarding protocols presented in [7] over an IP network composed of various LANs interconnected by routers. In summary, the mobility management protocol uses a centralized dynamic address resolution protocol inspired from the address resolution in IP over ATM networks. The central route resolution server, which can be the portal, will receive messages from each access points indicating the MAC address of the stations under their responsibility. It will be hence able to respond to routing queries and to inform all access points of routing updates when a station is roaming.

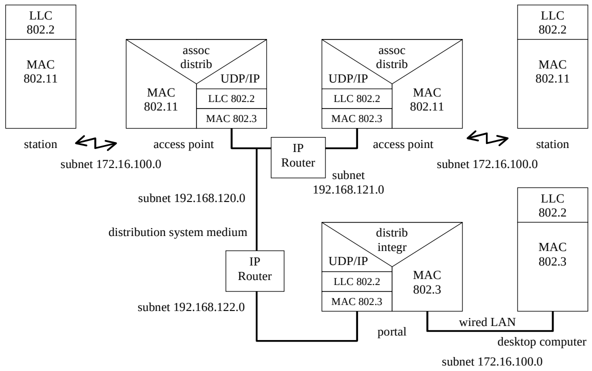

Figure 5. Infrastructure network using network layer addressing and a centralized dynamic route resolution protocol

IV. WIRELESS NETWORKS AND REAL-TIME TRAFFIC

A. Support of real-time traffic in wireless networks

The considered real-time communication is made of periodic and sporadic traffic. The periodic traffic consists in pieces of information that must be periodically transferred. Sporadic pieces of information must be transferred in a given timeframe.

Some proposals [3], [4], [5], [6] try to enhance the 802.11 Medium Access Control in order to support real-time traffic. A preferable option, in which the MAC remains untouched, can be studied further, in order to be able to use the available standard hardware.

B. Influence of roaming on real-time performance

The impact of roaming can be due to the following aspects :

- structure of wireless network,
- more message types,
- more traffic,
- overhead in usual traffic,
- presence of management protocol, etc.

If some still-to-be-defined techniques are implemented in order to support real-time traffic, the introduction or the genuine support of roaming may modify the behavior of the network and therefore have an impact on the performance of real-time services. The problem is then to implement roaming-independent support of real-time traffic. Another issue pertains to the real-time traffic management in wireless networks.

V. ONGOING TASKS

This work aims at designing and implementing real-time services over wireless networks with the support of mobility.

The study of the roaming techniques of 802.11 has lead to several solutions for its implementation, thus making the introduction of real-time services more complex. The bridging solution seems to be a good candidate for supporting real-time services, since it uses a transport protocol that has a low overhead and no mobility management protocol. On the other hand, the solution using network layer addressing and a centralized dynamic route resolution protocol may be required by certain application if the backbone network must include IP routers.

Furthermore, we hope to reuse the work that has been done on 802.3 for the design of a software layer over 802.11, in order to offer wireless real-time services [8], [9], [10].

Since the Bluetooth standard uses PPP for the LAN access profile, roaming induces lengthy connection establishment, which is usually incompatible with real-time constraints. This remains however an open topic. Depending on the results of the present work, some roaming techniques may be proposed for Bluetooth, along with implementation schemes of some real-time services over Bluetooth.

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