Dynamic Selection of Optimal Wireless Access Service

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Abstract

The number of different wireless access technologies is increasing, as well as the number of players on the market of Internet access. New terminals – both laptops and handsets often come equipped with more than one type of wireless access, like WLAN and 3G. When the number of options on many levels increases, the problem of selection becomes more important. This paper describes the problem of dynamic selection of optimal wireless access service, and then some of the current solutions and ongoing research are introduced.

1 Introduction

The number of different radio access technologies (RATs) and operators has been increasing over the past few years. Currently the mobile phone networks provide not only voice service but also packet data service. For example in Finland, GPRS is available practically everywhere and new 3G mobile networks are available in the biggest cities, as well as Wireless LANs, either operated by the same or different operators that run the mobile phone networks. Besides public access networks, more and more homes and enterprises install their own wireless networks.

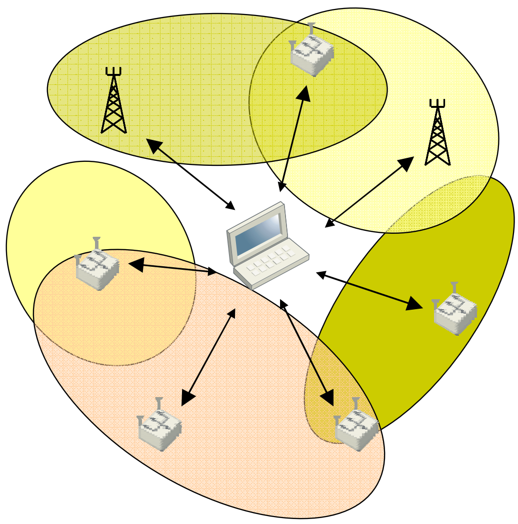

Figure 1: Multiple wireless accesses

The number of network technologies supported by mobile terminals is also increasing. Current portable computers usually have at least LAN and WLAN interfaces, some models may have also Bluetooth and analog modem – if not integrated, they can be added to the mobile system via e.g. USB interface. Mobile phones are going through similar development - besides GSM and UMTS radio they often come with Bluetooth and even WLAN.

The increasing amount of networks available and the increasing support for different networks in mobile terminals provide the mobile users with better network connectivity. However, an immediate question arises: if there are options, which one should be taken? More specifically, which network(s) should be used?

To answer this question we must first understand the different requirements set by the mobile users, operators, applications being used, and system status like battery usage and speed of movement.

This paper introduces the problem of *dynamic access selection*. In section 2 the problem is discussed. In section 3 an overview to current solutions is presented. In section 4 current research done in Ambient Networks and elsewhere is presented, and in section 5 the paper is concluded.

2 Problem

The problem of dynamic access selection is not limited to wireless or mobile devices, but solving the problem efficiently is more crucial for terminals that are moving, and especially for those that run on battery power. For any access network, wireless or cable, the problem is selecting the “best” access at a given time. The best access could be for example the cheapest access that provides the minimum QoS required by the running applications.

In some use cases it may be beneficial to use multiple accesses at the same time to gain e.g. smaller delay [9], but also because some services might be only available via a certain access network. In that case the access selection needs to be done also higher in the protocol stack, either per packet or per connection.

Different accesses may belong to different IP subnets. Selecting an access may result in an IP layer handover and e.g. Mobile IP [7] signaling. This should also be taken into account when doing access selection.

Basically access selection in a wireless environment can be divided to different sub problems:

- Selecting which interface(s) to power on
- Selecting which network to attach, if any
- Selecting which AP to attach, if any

- For application: which interface to use on a multi-RAT terminal

After the access selection a network attachment process may be required to obtain connectivity over the network, but that is out of scope of this paper. Network attachment would include everything required for the node being able to access the Internet, e.g. configuring IP addresses, AAA and mobility updates.

2.1 Current Wireless Access Technologies

Current available public wireless access networks are mostly built on IEEE technology (e.g. 802.11) or ITU/3GPP technology (GSM). These networks have different capabilities regarding bandwidth, delay, support for QoS, security etc. Also both groups create new versions of the standards, which create a situation where dozens of different types of networks may be deployed simultaneously. User may, for example, be in the coverage area of several 802.11a, 802.11b and 802.11g networks as well as 2G (GSM) and 3G (UMTS) networks.

2.2 Access Discovery

Selecting the access requires that the accesses are first discovered. Discovery of the wireless network is usually done by scanning the specified frequencies and listening to broadcast messages. There are two options, the mobile client can either wait for a periodic broadcast message (i.e. beacon) or it may actively request network information by sending a broadcast itself. The details depend on the RAT implementation.

An important question regarding access selection is that what information is available from the discovered networks. Usually the beacons are kept small to not waste the radio resources and they only contain information like the network name and maybe some information regarding the setup (e.g. supported security features with 802.11i [12]). This information might however be inadequate, as it doesn't currently say anything about e.g.

- Network level services
- Network load
- Pricing
- Roaming agreements

Consider the following example: the mobile user has a laptop which has an IPv4-only stack. When the WLAN hardware scans for available access points it makes the decision to associate with the access point to which it has the best signal-to-noise ratio (usual access selection criteria). However, the selected access point is connected to a network that only supports IPv6. The end result is that the applications on the laptop can't make any Internet connections. Similar problem arises when the access point is connected to a network that the user either has no subscription or the subscription cannot be negotiated on-line.

This problem can be solved in several ways. One simple way is to have previously configured information of the networks beforehand. The drawback is that whenever the networks change configuration it is not propagated to the mobile clients.

Another way is to put all possible information in the beacons. Here the drawback is that enlarging the beacon size reduces the available bandwidth for other data traffic, as it is broadcast typically every 100 ms to all mobile nodes (802.11) – even those that are already connected [11].

A better way to help mobile nodes in selecting the access is to make discovery two-stage. Only critical information like the network ID is put into the beacon, and extra information, like available services, is only available on request. This requires that the mobile client requests this second-stage advertisement from the access point and receives it as a unicast reply. With this kind of multi-stage approach it is also possible for a mobile client to send its identity to the access point, and it could then receive a "personalized" second-stage advertisement [5]. This advertisement could then include more private information like network load, if the identity of the mobile client can be authenticated. Typically the networks don't want to send load information to anyone who just anonymously listens to the access points.

It is also possible to send advertisements through other channels than the radio access in question. If the mobile user is already connected to the Internet, other accesses could be searched from a directory in the Internet [5]. The business models for this kind of directory service could be of several types. Either the mobile users themselves keep this kind of directory in a P2P fashion, the co-operating operators themselves or it could be a broker type of business where information of the available accesses are sold, or even bundled to selling of the access itself.

2.3 Access Selection

The most typical real life situation today is when a laptop user sits down and wants to have internet connectivity and he/she is facing the problem of selecting which WLAN network to use (see 2).

The problem is not that severe in the startup phase, as there are typically no applications running yet. But what happens when the user becomes mobile and goes out of the network coverage that he/she has chosen – while having a discussion over an IP phone call? Then the system should automatically select a new access to maintain the connectivity required by the applications.

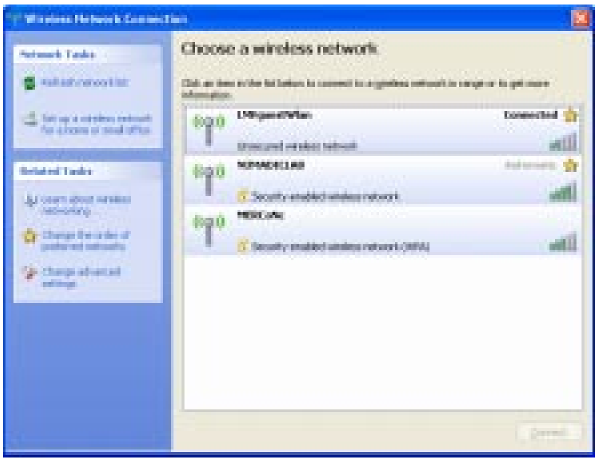

Figure 2: Where do you want to connect today?

First problem is to select which RAT to use, if the terminal has support for multiple different network technologies, like WLAN and 3G. It might not be the best option to have both switched on all the time. This decision depends on the running applications. Currently it could be possible to have a preference to use WLAN for multimedia and 3G for speech, for example, but in the future when the high-speed WCDMA radio accesses are available, the choice might not be that obvious. This is the case especially when both networks belong to the same operator and can be used with the same subscription and with the same rate.

Second step would be to select which network should be used. This requires running the discovery process on the selected RAT. Even if discovered accesses use the same RAT, they may differ in every other aspect:

- They belong to different administrative domains (operators)
- The services they offer may have different
  - IP connectivity
  - QoS
  - Security
- The cost of using the access may differ

After the network has been selected, there is still the selection of the used access point. This is typically a RAT internal process, and might be located in the mobile client, in the network, or they might work in co-operation. Currently in 802.11 based systems it is the mobile client that selects the access point that has the strongest signal quality. In the GSM networks (GPRS, UMTS) it is the network that does the decision.

It is also possible to use multiple accesses at the same time. Then the access selection is done once more higher in the networking stack. One way to do this is to separate different data streams over different accesses based on the application requirements or even split the data stream over different accesses on a per-packet basis [9].

At different stages of access selection some input parameters are required, as well as an algorithm that selects the best option from a given set. These input parameters can be either static or dynamic. Typically the static input is e.g. preferences or policies set by the user, like (“always use the cheapest access” or “always use WLAN if available”). Dynamic input is both the status of the mobile client (running applications, battery status, available protocols) and the network (signal quality, load, price). I have collected some example inputs into a table (see Table 1). These inputs have been grouped into different classes, and further each may have one or more of the following attributes:

- Discoverable before attachment
- Measurable by client
- Possible price effect

Inputs that are discoverable before attachment are information that can affect the selection of the network before attaching to it. Client measurable inputs can be proven correct or wrong by the client. For example the true end-to-end QoS can only be measured this way. The client may then store this data and use the history data in the future when selecting the access network. Some of the inputs may affect the price of using the network.

Depending on the user preferences, the priorities of different inputs can be evaluated. If the user wants to save money, then the price information is the most important input. If he instead prefers the best service, then inputs like signal quality and network load become more important than price. The preferences might be complex and not just “low price” or “good quality”.

3 Current Support for Access Selection

Access selection inside the RAT currently consists of two steps:

- Selection of the network
- Selection of the access point

Selection of the network typically happens based on some pre-configured information. In 802.11 systems the mobile client may have a configuration file that lists the network IDs that are usable, and possibly some keys or certificates that are to be used for security. For example, in wpa_supplicant [13] each network can be given a priority number, so the smallest number wins in the case that several known networks are in sight simultaneously. In the GSM system the terminal contains a SIM card that stores the identity and keys for the user. User is restricted to the subscribed network and networks that have made a roaming contract with the subscribed network. When the terminal is switched on, it searches for available networks and picks the one with the best signal quality among the allowed options. It is, however, possible for the user to list “preferred networks”.

Currently it is not possible to dynamically choose e.g. the cheapest network, but the user needs to obtain this information via e.g. WWW pages of the operators.

The selection of the access point (inside the selected network) is done by signal quality in WLAN. The only major drawback with this simple algorithm is that if there are many access points nearby, load balancing could be done also. This would require a RRM node which controls a set of APs and it is not currently used in WLAN networks

In GSM networks, selection of the access point is based on signal quality between the mobile terminal and the resource usage information. The mobile terminal makes measurements and the network makes the decision which access point the terminal should connect at any given time.

Access selection *between* available RATs in current systems, like laptops, is usually done manually by the user, by switching on and off the network interfaces. For example, in Windows XP, the default interface will be the one that has been switched on last. It is possible for the applications to explicitly select the outgoing network connection, but it is not possible to distribute optimal access selection into every running application. Therefore there needs to be a common function that controls the access selection.

UMTS release 7 will integrate WLAN with 3GPP network [2]. It will not change WLAN AP selection inside the WLAN network, it only defines the selection of the WLAN access, which should belong to the same network as the WCDMA access.

4 Research

There are currently several areas where access selection or multi-access technology are being worked on. In IETF, both Mobile IP and HIP allow the mobile node to do "vertical handovers" between access networks or even use several access networks simultaneously [10].

Another area where research for access selection is being done is the radio access networks. Selecting the optimal input parameters for access selection to gain maximum bitrates have been researched, like in [4]. The simulation studies showed that a terminal with WCDMA and WLAN interfaces could get good results with a simple access selection principle "use WLAN if coverage". This is valid when the WLAN offers significantly faster bitrates than WCDMA and/or with light traffic loads. However, with higher WCDMA bitrates (like in the coming HSDPA) and with higher loads in hotspots, better results can be achieved when taking the network load into account.

Research is also ongoing in transport area. One of the recent studies [9] show that when optimally combining the use of different access networks, delay and energy consumption per packet can be smaller than with just one single access. This, however, requires that the QoS parameters for each access are known. Also running the selection algorithm on real devices take CPU cycles away from packet handling and also consume battery.

When looking at all this work done with access selection on different areas raises the question that how will they work together. Thinking of the traditional network architecture – which layer should be responsible for access selection, and should it happen in the network or in the terminal? Ambient Networks is a project that has high ambitions to put different models and networks together.

4.1 Ambient Networks

Ambient Networks (AN) is an integrated project (IP) co-sponsored by the European Commission under the Information Society Technology (IST) priority under the 6th Framework Programme. It has over 35 partners including operators, manufacturers and academia. It aims to provide solutions for mobile and wireless systems beyond 3G [3].

Ambient Networks offer a new vision based on dynamic composition of networks. This goal is realized by introducing the Ambient Control Space, which controls the underlying networks and provides the users with "Ambient Connectivity" and new services.

One of the work items in the project is the Multi-Radio Access (MRA) architecture [8]. One of the key objectives of the MRA architecture is the efficient utilization of multi-radio resources. The main components of the MRA are Generic Link Layer (GLL) and Multi-Radio Resource Manager (MRRM).

The main task of the GLL is the collecting of measurement data from the underlying RATs and abstracting/normalizing it so that MRRM can optimize the combined resource usage of the access networks it controls. GLL can also act as a layer between the *Advertisement and Discovery* function in ACS and in the RATs.

MRRM controls the resource usage by managing *flow sets.* A flow is simply a generic name for a connection between two locators.

The *Detected Set* is formed by accesses that have been discovered. The *Candidate Set* contains accesses that could be used for a flow between the two ANs. The candidate set is filtered from detected set by e.g. applying some static preferences or policies. The *MRRM Active Set* lists the accesses that should be used for connections on MRRM level, and *GLL Active Set* may be a subset, if some accesses map to different GLL entities (see Figure 3). Filtering the active sets from the candidate set is based on measurements done by MRRM.

Both MRRM and GLL are parts of the Ambient Control Space, so they are not handling the actual data traffic. Instead, they control the existing mechanisms in RATs or the functions in RATs have extensions that allow communication with the ACS.

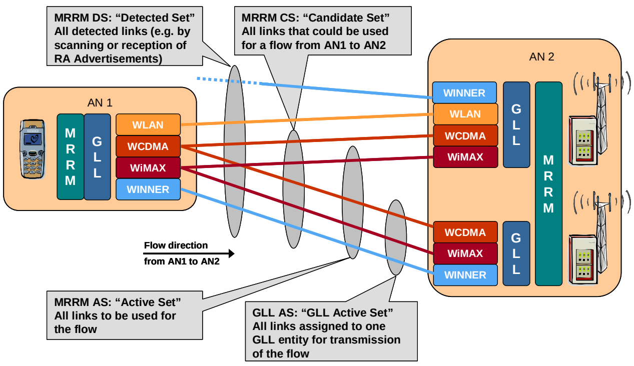

Figure 3: Multi-Radio Resource Management

MRA should enhance the performance for multi-radio mobile clients in areas where coverage areas of different RATs overlap. For example, a hotspot might have both 3G and WLAN access points (of different operators). If all mobile clients in the hotspot follow the simple rule “use WLAN if available” together with the WLAN AP selection logic to use the AP with best signal quality, the result might be that one WLAN access point gets overloaded while other access points have remaining capacity. By combining different sources of information (3G load, WLAN load, user movement, etc.) MRRM can control that the resources of both networks are used optimally, and the users get the best possible service.

Besides GLL, Ambient Networks is also considering other sources of information to base the access selection on, like user input, application requests, context information, dynamic roaming agreements etc.

5 Conclusions

The number of different wireless access technologies is increasing, as well as the number of players on the market of Internet access. New terminals – both laptops and handsets often come with support for more than one type of wireless access, like WLAN and 3G. It is at least the mobile users’ interest to be able to use accesses of different operators with the same terminal, if not for saving money, then for having better coverage for Internet access.

New Internet based applications, like VoIP, are getting more and more popular. A voice call can survice breaks of few hundred milliseconds without disruption in service quality.

Taking all this progress on different fields into account, the problem of dynamic access selection becomes quite important. The problems are with the number of inputs that should be considered together with the limited processing capabilities and battery lives of mobile devices. Some example inputs have been collected into a table and categorized to some extent based on different attributes. It can be argued that it is the client that has the ultimate decision which of the input parameters are most important.

Research and standardization are done on many fields: IEEE, IETF and 3GPP have all different ideas and interests of access selection. Different research groups are looking at different parts of the networking system trying to solve the problem or to find optimal algorithms for access selection. New projects, like Ambient Networks, try to take “everything” into account, to be able to provide the users best possible service, any time, anywhere. The following years, and the market, will show which approach was “the best”.

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Appendix

Table 1: Example of inputs for access selection

Class	Inputs	Example	D	M	PE
Access network status	Bandwidth	11 Mbps	X	X	X
	Signal quality	78%	X	X	
	Load	25%	(X)		
	Delay	50 ms		X	
	End-to-end QoS	1 Mbps, 75 ms		X	X
	Available services	IPv4	(X)	X	X
Access network attributes	Security	WPA2	X	X	X
	Coverage	1 AP only			X
Terminal status	Running applications	VoIP call	X	X	
	Battery level	2 h left	X	X	
Terminal attributes	Available network interfaces	WLAN, 3G	X	X	
	Available network protocols	IPv4, IPv6	X	X	
Context information	Movement speed	42 km/h	X	X	X
	Movement direction	240º	X	X	
	Geographical location	N 60º 08.532 E 024º 40.034	X	X	X
Business parameters	Price	€ / MB	(X)	X	X
	Available credentials and subscriptions	SIM card	X	X	X
User preferences	Preferences, rules	”Use cheapest”	X	X	X

D = Discoverable before attachment   M = Measurable by client   PE = Possible Price Effect