Network Selection for Mobile Nodes in Heterogeneous Wireless Networks using Knapsack Problem Dynamic Algorithms

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***Abstract* — With the accelerated proliferation wireless networks ranging from GPRS and EDGE to high speed networks such as HSPDA and Mobile Wi-Fi, network selection by mobile nodes will benefit more from knowledge of Network Capability of candidate networks. Network selection is important for handover in heterogeneous wireless environment. User Profiles/Needs and Network Capability will greatly influence the next logical step after network discovery, which is Network Selection. We examine the Dynamic Network Selection paradigm that uses User Profiling/needs to rank networks for selection and ignore networks with less capacity than required , using the Knapsack problem 0/1 Dynamic algorithm and the Knapsack problem Optimization Algorithm.**

***Keywords* — Dynamic Selection, Heterogeneous Wireless Networks, Mobile Nodes, Network Capability, Network Selection, User Profile/needs.**

I. Introduction

The proliferation of overlay and complimentary networks offers mobile nodes the reality of ubiquitous service access across the vast areas of coverage. [1]. However mobile nodes are at times exposed to disparate networks for which adequate knowledge that allow the mobile nodes to take advantage of the facilities available on the candidate networks may not be available. The major effect of this, being inefficient use of network resources. We discuss the importance of network discovery in pursuit of user satisfaction and efficient use of network resources.

Several approaches can be taken by mobile nodes to obtain information about candidate networks prior to making a selection of the target network or networks from the possible candidate networks. It is possible that selection could be done in a heterogeneous wireless network environment or homogeneous networks with different network capabilities and Quality of Service (QoS).

In heterogeneous wireless environments such as in (Fig. 1), different access means could employed to access services through vertical handoff. The vertical handoff could involve switching physical interfaces. If a software defined radio is employed this could entail switching frequencies through a programmed application that is responsible for network access. Different authentication methods, different credentials and different profiles could also be in place, thereby resulting in totally different experience for the user within the same environment.

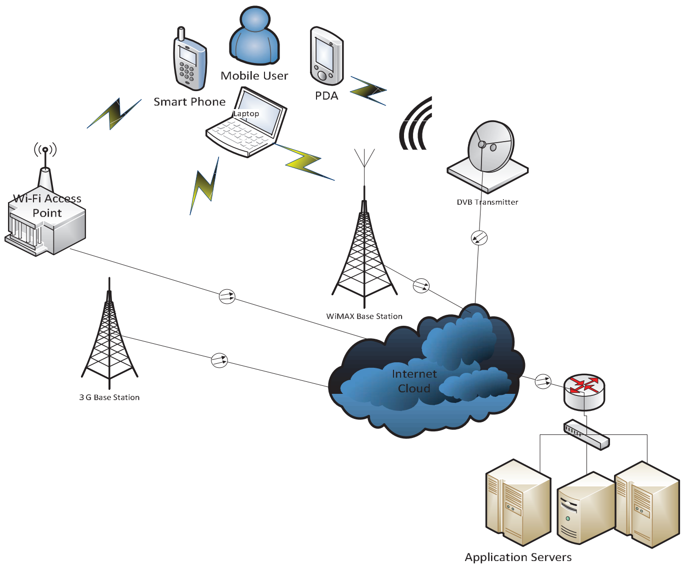

Fig 1: Heterogeneous Networks Access

In homogeneous networks such as in (Fig. 2), a simple change in domain, or change of current attached network point or base station or even a change in Service Set Identifier (SSID) could mean a whole different set of services available to the user. Change of service provider can also mean in totally different experience for the user. The use of the same technology or platforms does not guarantee mobile nodes of the same experience.

Therefore, if as much information can be obtained at the network discovery phase, network selection and handover

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to the target network will be more informed. In this paper we examine several network discovery frameworks that would assist in availing as much information to the mobile node for the seamless handover that is user profile aware.

The organization of the rest of the paper is as follows, in Section II, we discuss the available frameworks for network discovery, in Section III, we look at related work, and in Section IV, we examine the network capability factor in network discovery and selection, and in Section V, we give an overview of the open areas of research.

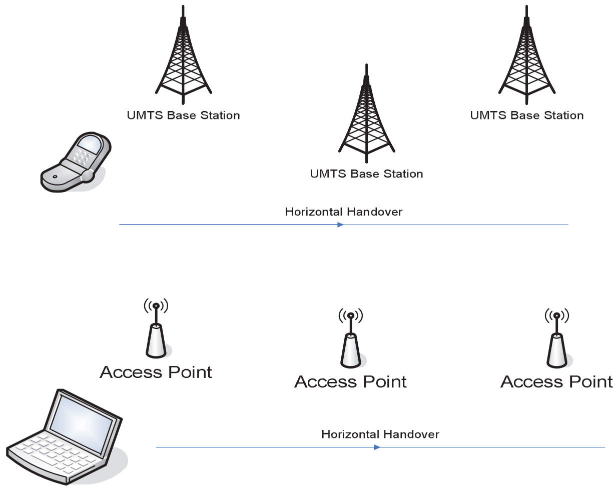

Fig 2: Homogeneous Network Access

II. Network discovery frameworks

Several frameworks have been developed to assist mobile nodes with the process of discovering potential network attachment points should there be a need to execute handover.

The Internet Engineering Task Force (IETF) through Request for Comments (RFCs) has basic frameworks that indicate the expected operational standard for network discovery in homogeneous and heterogeneous environments. RFC 5113 [12], Network Discovery and Selection Problem, defines network discovery as the mechanism nodes use to discover available networks. The RFC discusses a number of aspects of network discovery and selection. It distinguishes between passive and active network discovery. In which, the former involves merely listening for network announcements and the later involves fetching networks announcements. The document also discusses Network Capacity Discovery, which focuses on identifying the services offered by networks within the reach of the mobile node

RFC 4861[2], Neighbor Discovery for IPV6, deals with network discovery with greater emphasis of network nodes in the neighborhood such as network attachment point and network routers in IPV6 environments. As the uptake of IPV6 worldwide is gaining pace, the framework is very vital at this transition stage from the IPV4 era to the IPV6 ear. This framework provides for the same nodes with this information the ability to pass this information to currently attached mobile nodes in the network discovery phase. Information of the neighbors is obtained and exchanged through Neighbor solicitation, Neighbor advertisements, Router solicitation and Router advertisements.

RFC 4066 [3], Candidate Access Router Discovery (CARD), aims to enable seamless IP-layer handover of a mobile node (MN) from one access router (AR) to another, the mobile node should discover the identities and capabilities of candidate ARs (CARs) for handover prior to the initiation of the handover. The process of discovery of CARs involves identifying their capabilities, which is of interest for our paper.

The Institute of Electrical and Electronic Engineers (IEEE) released the generic standard IEEE802.21 also known as Media Independent Handovers (MIH) as of January 2009 [4]. The standard proposes 3 major services and a logical function that can used to assist nodes in the process of handover between heterogeneous wireless networks, namely, the Media Independent Information Service (MIIS), Media Independent Event Services (MIES) and Media Independent Command Services (MICS) [4]. The MIES can provide nodes with warnings of deteriorating signals, allowing nodes to look for new network attachments points. The MIIS can provide the information of available networks attachment points. The MICS allows the node to direct handover to selected network.

An open source version of the 802.21 standard called Open Dot Twenty One (ODTONE) [5], is a product of the Heterogeneous Networking Group (HNG) in the Advanced Telecommunications and Networks Group from the Instituto de Telecomunicações. ODTONE provides a framework for the MIH implementation in multiple platforms, considering both hardware and software. It provides a framework platform for development by the academic world before the commercialization of the IEEE standard by different vendors in their own implementations.

The 3rd Generation Partnership Project (3GPP) also has work that has culminated in the Access Network Discovery and Selection Function (ANDSF) development [6]. The ANDSF seeks to utilize 3GPP service providers' services to notify 3GPP compliant mobile nodes of possible available networks and services that are non-3GPP [1]. The Technical Specification provides for availing Discovery Information to mobile nodes that details the candidate networks for possible attachment.

Proprietary solutions such as the Cisco Discovery Protocol, Nortel Discovery Protocol, Cabletron Discovery Protocol and Extreme Discovery Protocol together with the IEEE802.1AB standard, Link Layer Discovery Protocol generally provide for the functions of neighbor discovery in Ethernet networks. In today's ubiquitous service access mobile nodes may perform handovers between Ethernet connections and Wireless connections and these protocols can provide the mobile nodes the much needed information for network discovery via the current network node.

III. Related Work

A Network Information Repository (NIR) is suggested in [7], to function with a Cell Broadcast Center (CBC) to supply information to mobile stations with updated network information. In their solution the mobile station can also fetch information as opposed to the network pushed information, which they claim allows for timely information to the mobile station to ensure seamless connectivity or handover between available Radio Access Networks. The NIR supplies the CBC with network information which in turn supplies the information to the mobile station in the general algorithm proposed. The approach is generic and could be extended to incorporate user profiling.

A combined solution utilizing the MIH and ANDSF is proposed in [8]. Contrasting the functionalities of MIH and ANDSF, the authors attempt to identify the highlights and drawbacks of the two as independent implementations. They claim that the MIH does not inform the source network of the mobile node's move to the target network which can result in packet loss. Using ANDSF they claim to be able to send this information to the previous attachment point thereby giving the ability to recover the data that would have been sent to the previous network point.

An enhanced CARD mechanism in [9], aimed at resolving, the problem of a single point of failure, increased signaling load and high latency, through the use of a Multi-hop Candidate Access Routers (MHD-CAR) Discovery is proposed. The authors claim the MHD-CAR mechanism enhances operational reliability, robustness of seamless and fast handovers without increasing the overhead signaling. Their work addresses the technical needs for network discovery but does not offer any view of user applications.

A hierarchical neighbor discovery scheme is proposed in [10], with the reasoning that the amount and detail of information pertaining to network Points of Attachment of a single access network and the combination of these details with a number of other access networks that may be for different operators may be too large. For network discovery the hierarchy suggested is composed of mobility zones level, the zones MIIS servers' level, the local MIIS server's level and the global MIIS server's level. Hierarchically information is passed down from the global MIIS level, to local MIIS level to Zone MIIS level to the mobile node. It is a good technical solution without consideration of user applications needs.

Focusing on Quality of Service (QoS) aspects [11] discusses the problems experienced across several administrative domains in trying to satisfy the QoS requirements. They suggest negotiation of Service level agreements with neighbor domains in an attempt to meet the QoS requirements. In our view the negotiated QoS for the handover should at least match or better the existing Service level agreements that the mobile node.

IV. NETWORK CAPABILITIES AGAINST USER NEEDS

Different networks have different capabilities and these capabilities should be availed to the mobile node during the network discovery phase in order to assist the mobile node make appropriate network selection decisions. Fig. 1 depicts a mobile node that has access to several different networks. The mobile node could be a smart phone or a Personal Digital Assistant or a laptop with either multiple interfaces or software defined radios.

In reality a lot of other factors may be utilised to determine complex user requirements that should in turn guide the network selection process after the network discovery process, however we examine simple cases in order to analytically evaluate network capabilities and user needs to determine network selection that could be employed beyond network discovery.

In this section we use the knapsack problem to analytically model Network Discovery and Selection that uses the knowledge of user application needs and network capabilities. We utilise the 0/1 dynamic programming approach to decide if the application will be connected via which of the available networks.

Our candidate network is our current knapsack with capacity (*C*) and the user application needs are objects (*j*) numbered from 1 to *n* to fill the knapsack with. Using binary vector (x_j) to represent the selection of candidate network if satisfying the user application needs,

$$x_j = \begin{cases} 1 & \text{If selected} \\ 0 & \text{Not selected} \end{cases}$$

Thus for each user application (object *j*) considered that required bandwidth *b,* we consider the candidate network capacity and only select if the required bandwidth will be satisfied, and this is expressed mathematically as follows.

$$\sum_{j=1}^{n} b_j x_j \le c$$

The approach used is not optimal as user applications with far less needs could occupy a network with far higher capacity than necessary thereby rendering the rest of the capacity idle. Thus to maximize network capacity utilization if selected we, select networks with capacity close to the need. Therefore, we can assume the optimal utilisation of the knapsack by object requiring the maximum *m*

$$\text{maximize} \quad \sum_{j=1}^{n} m_j x_j$$

$$\text{subject to} \quad \sum_{j=1}^{n} b_j x_j \le c$$

$$x_j = 0 \text{ or } 1,\ j = 1, \ldots, n$$

We can from the above functions formulate the following algorithm for Maximal Output M

```
int b, k;
for (b=0; b <= C; b++)
    M[b] = 0
for (k=0; k<n; k++) {
    for (b = C; b>= b[k]; b--) {
        if (M[b – b[k]] + m[k] > M[b])
    M[b] = M [b – b[k]] + m[k]
}
}
```

Simplified, the above algorithm and functions could be shown as follows. If we have different users with different constant known networks capacity needs, as depicted in Table 1, where network capacities are shown in Table 2, then selection from our knapsack algorithms will be as shown in Table 3.

TABLE 1: USER APPLICATION NEEDS.

User Application	*Ave.Traffic Size*
Instant Messaging(IMS)	150 Bytes
E-Mail without Attachment	50 KBytes
MP3 Audio download	5 MBytes
MP4 Video download	50 MBytes

We assume all users have devices that are capable of accessing General Packet Radio Service (GPRS), Enhanced Data-Rates for GSM Evolution (EDGE), 3G-High Speed Data Packet Access (HSDPA) and Wireless-Fidelity (Wi-Fi) networks such as smart phones e.g. Android phones, Personal Data Assistants (PDAs) and tablets in the market.

In Table 2 we show the average lower end specification of the GPRS, EDGE, 3G (HSDPA) and Wi-Fi network.

TABLE 2: CANDIDATE NETWORK CAPABILITIES.

Network	*Speed(Low Spec)*
GPRS	9.6Kb/s
EDGE	177Kb/s
HSDPA	1.2Mb/s
Wi-Fi	11Mb/s

In Table 3 we depict the network selection if the networks are discovered by different mobile nodes with different requirements from the network as depicted in Table 1, without taking into consideration any other factors that may be used by the mobile node from details obtained in the network discovery phase. These are optimal selections that will satisfy the basic user applications in our analytic evaluation.

TABLE 3: NETWORK SELECTION INFLUENCED BY USER APPLICATION.

User Application	*Network Selection*
IMS	GPRS
E-Mail	EDGE
MP3 Audio download	HSDPA
MP4 Video download	Wi-Fi

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V. FUTURE WORK

The evaluation of concurrent application requests to one network either from the same user device or several users in the vicinity may also greatly influence the network selection utilised. Utilisation of user profiles, user or network context may also influence network discovery and network selection in heterogeneous autonomic network environment.

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