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Handoff in Heterogeneous wireless networks by Adjusting the Transmission Power [RSS]/Rate

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Abstract- **The main objective of this paper is to evaluate the conditions and restrictions under which seamless multimedia Quality of Service (QoS) provision across 4G is possible. One vital component for the provision of seamless multimedia session continuity is the QoS consistency across these heterogeneous networks. This is vital indeed because without QoS consistency the multimedia session will experience different QoS levels in these network domains and hence seamless continuity will not be doable. Hence QoS consistency turns to be a quite challenging issue. In this paper, power management algorithms are developed to control the coverage of access points and base stations to handle dynamic changes in mobile resources. The optimization objective is the maximization of the overall throughput with the satisfaction of the QoS metrics for multimedia communications. The revenue gain is also significant over the scheme in which vertical handoff is supported.**

Index Terms— **CDMA, WLAN, QoS heterogeneous networks, transmission power, vertical handoff.**

I. INTRODUCTION

Aim of the Future wireless networks is to provide universal ubiquitous coverage for different radio technologies. In this a multi-mode mobile node (MN) provides connectivity to several wireless access networks [1] such as Wireless Local Area Network (WLAN), Universal Mobile Telecommunication Systems (UMTS), CDMA2000 (Code Division Multiple Access) and Wireless Metropolitan Area Network (WMAN)) simultaneously. A large variety of applications utilizing these networks demand features such as real time, availability across different access technologies in a seamless way. However, the requirement of mobility raises new issues related not only to handoff management, such as Low Disruption Time [2], but also the Quality of Service. Any mobile system in such integrated networks should be able to adapt to changing access networks and changing environments automatically without human-intervention to make mobile computing feasible. The integration of different technologies increases system complexity and complicates the design and performance evaluations. Consequently, developing an accurate traffic and mobility model emerges as a crucial requirement for the design of various processes such as location updating, paging, radio resource management and technical network planning [3].

Recent studies show that WLANs and Wide Area Networks, such as Code Division Multiple Access (CDMA) cellular networks, should coexist to offer Internet services to users [4], [5]. WLANs offer relatively high data rates. It is easy to find WLANs in class rooms, offices, airports, hotels, and malls. On the contrary, CDMA cellular networks support low data rates, but offer a much wider coverage area that enables ubiquitous connectivity.

In this paper, a heterogeneous wireless access environment consisting of AP (IEEE 802.11 WLAN), BS (CDMA cellular network), and IEEE 802.16 WMAN radio interfaces as shown in fig. 1 is considered.

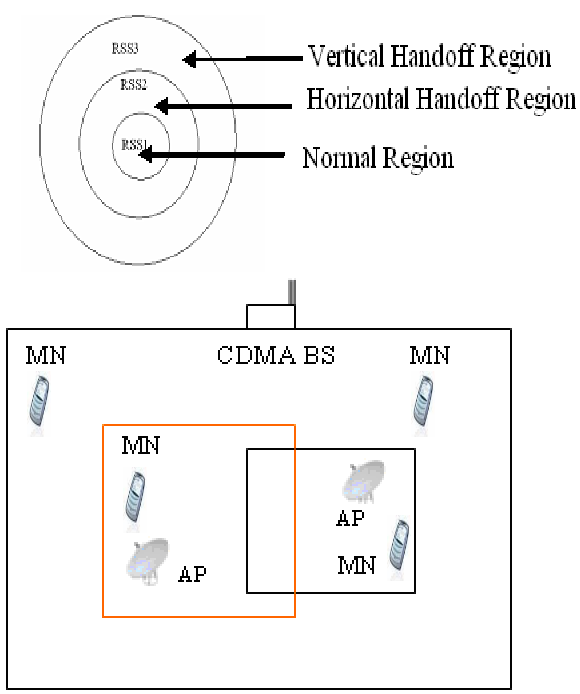

Figure 1. A scheme showing RSS in a WLAN and handoff regions in a heterogeneous network

A mobile node (MN) with multiple radio transceivers (eg, software radio) gets connected to these radio access networks simultaneously.

Consider a geographic region that is entirely covered by a WMAN Base Station and partly covered by Cellular Base Station (BS) and partly by WLAN Access Points (APs). Since WLANs and Cellular Access technologies are complementary and gained wide popularity, focus is given on these technologies in this paper. But the developed algorithms are widely applicable to any access technology and application.

In [6], performance criteria have been introduced to evaluate seamless vertical mobility such as network latency, congestion, battery power, service type etc. A Mobile Node (MN) can exist at a given time in the coverage area of a CDMA Base Station alone. But due to mobility, it can move over to the region covered by more than one access networks, namely the CDMA BS and an 802.11 AP. However 802.11 Access Point coverage area is usually contained within CDMA coverage area. A Wi-MAX coverage area can overlap with WLAN and/or CDMA coverage areas. In dense urban areas, even the coverage areas of multiple CDMA Base Stations can overlap. Thus at any given time, the choice of an appropriate attachment point (BS or AP) for each MN needs to be made with vertical handoff capability, service continuity and QoS factor of the MS can be significantly enhanced. Thus, multiple access technologies as well as multiple operators are typically involved in vertical handoff decisions.

Although some work has been done to integrate WLANs/CDMA networks, most of the previous work concentrated on architectures and mechanisms to support roaming and vertical handoff. The utilization of overall radio resource optimally subject to quality of service constraints has not been studied in detail in this coupled environment.

Previous studies of public-area wireless networks have shown that client service demands are highly dynamic in terms of both time and day and location, and that client load is often distributed unevenly among wireless access points (APs/BSs) [7], [8]. The authors of [9] propose a vertical handoff decision method that simply estimates the service quality for available networks and selects the network with the best quality. However, there are still many challenges in integrating cellular networks and WLANs or any combinations of heterogeneous networks in general.

The process of network switching has three phases [10], network discovery, handoff decision and execution. The decision phase played a crucial role in resource utilization and user/Application quality of service requirement. The vertical handoff process of a next generation wireless system was modeled and evaluated by an analytical performability model. The performance of decision system is evaluated through the sensitivity analysis of VHO decision parameter. In [11], Morkove Decision Process Model based adaptive vertical handoff with RSS prediction in heterogeneous wireless network has been introduced. An AP can get seriously overloaded even when several near by APs are lightly loaded. This is because a majority of the WiFi cards associate with the APs with the loudest beacons. ie, Received Signal Strength (RSS) is maximum irrespective of the neighboring network status.

II PROBLEM STATEMENT

In the system Model under consideration, there are multiple service providers who non-cooperatively offer wireless access services to the users, each of the service providers aim to maximize their utility. An AP/BS- centric approach to transparently balance load across the heterogeneous network is proposed here. The main challenge in this approach is to discover appropriate transmission power for each AP/BS.

Let,

C_a → Maximum capacity which an P_{ai} can provide

C_b → Maximum capacity which a BS ci can provide

X → Number of APs

Y → Number of BSs

MN → The Number of mobile nodes.

RSS_{ij} → Received power from AP_{ai} or BS ci

P_i → Power of APs/BSs

R_j → Requested Bandwidth (data rate) by MN_j (user demand)

θ_{ij} = 1 if the MN is associated with AP_{ai} ($1 \le i \le X$) or BS ci ($X+1 \le i \le X+M$)

Based on the notations listed above, In this paper competitive environment is assumed, ie. Each client (we also use the term mobile), demands to transmit at largest possible data rate. Moreover, a client is in outage if it can not achieve its minimum required data rate.

III. MAXIMIZING THROUGHPUT FOR CONTINIOUS POWER

In this section, the power control algorithm for the cases when APs can adjust their power (continuous power) to any value is presented. The algorithm requires APs to estimate the received power at different clients. It only assumes the received power at any location is proportional to the transmission power, which holds in general even under obstruction. The discrete power assignment algorithm requires only the load information of the particular AP is needed.

The received power at the MNs is estimated as follows:

The received power, RSS_{ij} is a function of transmission power P(i) and the distance between the MN and AP or BS, d(i,j). Hence the function can be written as

$RSS_{ij} = a * Pi / d(i,j)^{\alpha}$ (1)

where 'a' is a constant.

When the wireless propagation is under obstruction, the actual wireless propagation can be introduced approximately with a virtual distance. In this the virtual distance follows the equation (1). More specifically it can be written as

$RSS_{ij} = a' * Pi / (d'(i,j))^{\alpha'}$

Where α′ is the virtual attenuation factor and d′(i,j) is the virtual distance

A. Maximizing Throughput for Heterogeneous Demands

A power control algorithm is developed for heterogeneous user demands. There are two cases are considered, splittable and unsplittable demands. Under unsplittable, client demand is satisfied completely and motivated by real-time services, such as video streaming. In these services, if the demand can not be completely satisfied, it is better not to serve the demand because the video requires certain bandwidth to achieve an acceptable performance. In the case of splittable demands, the throughput from a demand is proportional to the fraction of the demand that is provided by APs or BSs. The main application of this setting is in the best- effort services such as web browsing.

Here, an algorithm based on linear programming (LP) is presented.

Discover Association Algorithm

(i) Based on the notations listed in section II the weighted bipartite graph G(A,C,E) can be obtained, where A is the set of APs or BSs, C is the set of Mobiles. There is an edge (E) between each APi/BSi to mobile j. The weight of the edge from AP/BS i to mobile j is assigned to $w_{ij} = \ln(d(i,j))$.

(ii) Discover the minimum weight bipartite matching in G, where the nominal capacity of an AP i is C_a and BS i is C_b and the nominal capacity of every mobile is 1. In other words, a MN can be mapped with at most one AP or BS and an APi can be matched to atmost MN_j mobiles.

For each AP_{ai} in A $(1 \le i \le X)$,
the capacity on AP_{ai} is

$C_a = \sum e^{a}_{ij}$ for $1 \le i \le X$ and
the capacity on BS_{ci} is

$C_b = \sum e^{b}_{ij}$ for $1 \le i \le X+Y$

The minimum weighted perfect matching problem is formalized as follows:

Let, R_j → Requested Bandwidth (data rate) by MN_j (user demand).
M → The set of mobiles

$$\text{Minimize} \sum_{i \in M, j \in A} w_{ij}\, \theta_{ij} \qquad (2)$$

$$\text{Subject to } \forall i \in C_a \sum_{j \in A} \theta_{ij} = 1$$

$$\forall j \in A \sum_{i \in M} R_j\, \theta_{ij} \le Mj$$

$$\forall\, i \in M,\ j \in A \quad \theta_{ij} \ge 0$$

In this linear program, $\theta_{ij} = 1$ shows that mobile i is mapped to AP_j and also there are two constraints. The first one indicated that each mobile is assigned to at most one AP or BS. The second one shows that APj is assigned to at most Mi mobiles. Since it is a bipartite graph, the integrality gap of the above linear program is one. Hence, there is an optimum solution with 0-1 variables.

The dual of the above LP is as follows.

$$\text{Maximize} \sum_{i \in M} x_i + \sum_{j \in A} M_j \pi_j^{*} \qquad (3)$$

Subject to

$$\forall\, i \in M,\ j \in A \quad R_j x_i + \pi_j^{*} \le w_{ij}$$

$$\forall\, j \in M \quad x_i \ge 0$$

The Algorithm to discover power assignment is as follows:

1) Find the optimum extreme point solution θ_{ij}* to the LP (2) and its corresponding dual optimum x_i* and π_j* to the dual LP (3).
2) Set $P_j = e^{\pi j}$
3) Connect every mobile i to the APj for which θ_{ij} =1 if such j exists, otherwise do not serve i.
4) Scale all the powers by the same factor such that $Pj \ge M_j$ is the minimum power by which AP j can reach all the clients that it has to serve.
5) If $P_j \le M_j$ connect MN to BS.

B. Maximizing Throughput for Discrete set of Powers

In this, the powers of APs and BSs can only take certain discrete values. APs from many vendors have only a handful of power levels (eg, Cisco Aironet [12]. In this section, the power assignments algorithm is given as follows.

Assume that the power of an $AP_p \in A$ can be set to one of the values from the set $\{P_1^p, P2p, \ldots P_n^p\}$ where $P_1^p \geq P_2^p \geq, \ldots \geq P_n^p = 0$

In this algorithms the power of all APs are set to maximum power level, P_1^p

i) Set the maximum power P_1^p to each AP_p

ii) While there exists an AP p of power P_{ip}^p, $1 \leq ip \leq h$ such that the AP can not accommodate all the demands assigned to it, then change the power of AP p to P_{ip+1}^p and no AP matched with the mobile demand, connect it to BS.

iii) Among all power configurations generated in the above step, choose the one that gives the highest throughput.

The above algorithm is very efficient. The number of iterations in the while loop is atmost hK. Hence, the algorithm has a polynomial running time.

IV. DYNAMIC POWER ASSIGNMENT

When the MN's demands are continuously changing, it is frequently looking for an association without requiring many mobiles to handoff to different APs or BSs. Hence a dynamic algorithm is developed for this purpose.

It is assumed that a client (mobile) will not switch to a different AP or BS unless its RSS from a new AP is improved by a threshold. Multiple WLAN coverage areas are usually contained with in a CDMA coverage area. A Wi-MAX area can overlap with WLAN and/or CDMA coverage areas. In dense urban areas, even the coverage areas of multiple CDMA BSs can overlap.

A client i to be happy if it is connected to an APj, or BSj and the RSS from j is at least $1/\gamma * \max(RSS_a)$ for all $a \in A$, where $\max(RSS_a)$ denotes the maximum Received Signal Strength from APs or BSs and γ is larger than 1.

The following algorithm starts with the existing assignment of MNs to APs/BSs and makes a number of changes to the existing assignment so that all the MNs are happy after the changes. Based on the auction algorithm in [13], it could be written as,

i) Start with the current power assignment and current association of clients to APs or BSs,

ii) Repeat the following procedure until either all the clients are happy or all the APs/BSs are completely utilized:

a) If a client is not happy, it tries to find an APj for which $\pi_j - w_{ij}$ is maximized,
It sends an association request to APj

b) APj accepts the request when it has capacity. Otherwise the client will connect to BSj. During this time the APj sorts the clients that are connected or requested to connect in the decreasing order of their $x_i - w_{ij}$.

Let n be the highest index such that client 1, 2,……n can be served by APj.
j accepts these clients and set its power to $x_n - w_{nj} - \varepsilon$

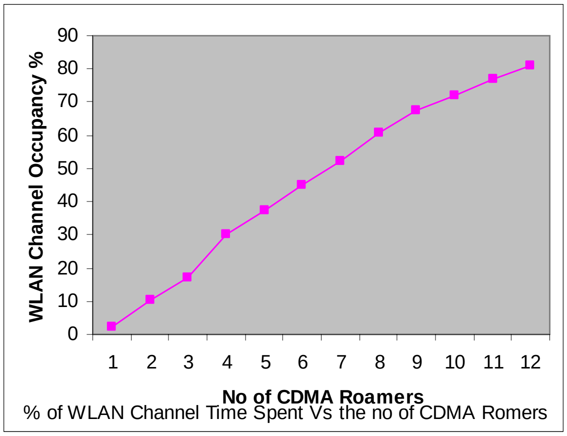

Figure 2. Percentage of WLAN channel time spent versus the number of CDMA roamers.

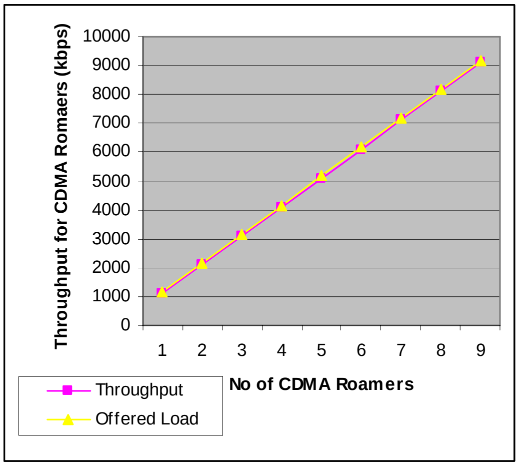

Figure 3. Traffic load and throughput and for delivered video packets versus the number of CDMA roamers.

The powers of all APs are decreased several times at the end of the algorithm it can be normalized by multiplying all the power values by a constant δ. This will not affect the assignment of clients to APs or BS s. Moreover, the changes in the powers are powers of γ, the algorithm converges to the right solution very quickly.

V. PREFORMANCE EVALUATION

We consider the service areas shown in fig.1. In this case the channel rate is 11Mbps and the maximum throughput obtained through EBA in a WLAN is 7 Mbps [14].For CDMA cellular wireless access, the transmission bandwidth is assumed to be 5 MHz. The total transmission rate in each CDMA cell is 2 Mbps. For the IEEE 802.16 based wireless access ,the transmission rate is 10Mbps in a single cell. The parameters for network utility function are set as follows: ω=1 and α=0.7. Thee parameter for the utility function for the connection (σ) is 0.7,0.8,and 0.9 respectively for new connection, vertical handoff connection and horizontal handoff connection become zero if the corresponding blocking and dropping probabilities become higher than 0.3, 0.1, and 0.05, respectively.

Fig. 2. depicts the channel occupancy versus the CDMA roamers admitted in the WLAN. Observe that the occupancy increases linearly and that the 40% of channel capacity available is reached for 07 CDMA roamers.

Fig.3. depicts the throughput achieved with the CDMA roamers.

VI. CONCLUSION

This paper outlines a handover strategy for heterogeneous wireless networks. The algorithms presented above provide capacity where it is needed and when it is needed. Moreover more clients are satisfied and the overall utilization of the network is improved. Cell breathing is implemented by adjusting the power of each AP / BS in the network. The dynamic version of the algorithm can adapt to changes in client demands by maximizing the total satisfied demand while limiting the number of clients that switch APs or BSs.

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