A Cross-Layer Vertical Handover Decision Model for Heterogeneous Wireless Networks

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Abstract

Vertical handover in heterogeneous wireless networks is a strategic decision due to its profound impact on mobile applications and their performance. Primarily it's an issue of network availability and secondarily it is a question of choosing best available service. This paper presents a Cross-layer Vertical Handover (CVH) decision model that maintains the pre-decision load of vertical handover processing on two layers i.e. application layer and a thin shim layer between the network and data link layer. A match-maker service help in handover decision on the basis of best match of application demands with available connectivity options. The results show low-latency, highly consistent vertical handovers during mobility and improved performance of applications with respect to throughput and reliability.

1. Introduction

The presence of multiple wireless link access technologies has improved the chances of connectivity at a particular point at the expense of complex handover decision provided mobile node (MN) is equipped with multiple interfaces. The enhanced connectivity options provide real-time applications with stringent quality of service (QoS) requirements, some leverage by simultaneously connecting to more then one wireless interfaces or making an efficient handover decision to a link the provide desired service level at considerable low cost. The simultaneous connectivity with different network technologies may provide multiple chunks of data rate that can significantly improve the performance of real time services like video conferencing, net meeting and m-commerce but cost of service may also increase. In contrast an efficient decision to switch to the best available wireless service that meets maximum needs of currently running mobile applications on mobile station (MS) can be more desirable. This may require a handover decision smart enough to provide service not only to a level of acceptability but also for duration large enough to justify the handover overhead.

During mobility, handover decisions result in change of subnet which means that additional delays may also be involved due to layer three negotiations. Fast mobility results in a high frequency of handover events that may cause major performance degradation. Mobile IPv4 and IPv6 [1] along-with different micro-mobility schemes[1] provide basic infrastructure for handling mobility but their handover decision base on agent solicitations (AS) and agent advertisements (AA). Link layer being the first mobility sensor, can contributes through mobility triggers as specified in Media Independent Handover specification [9] can cause ping-pong effect at the layer-3 mobility management schemes due to high rate of mobility event signaling caused by availability of multiple link interfaces. A shim layer is identified for handover decision maker in presence of multiple link interfaces like Wi-Fi, Wi-Max and cellular technologies. The link layer triggers provide best link layer characteristics but the inherent limitation of wireless media like short-term fading, and channel interference may raise frequent triggers which may lead to frequent redundant handovers causing serious performance bottleneck. In contrast to horizontal handover, where handovers are essential due to change in physical link characteristics, vertical handover is relatively optional procedure which should perform match-making between the running applications connectivity requirements and available connectivity services. Such match-making can only be possible through continuous tracking of two sets of information mentioned above. Further we need to estimate possible duration of availability of the various services which vary considerably.

Considering above mentioned arguments related to link characteristics along with the fact that the dynamic nature of application requirement can easily be

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monitored at application layer, this paper presents a Cross-layer Vertical Handover (CVH) decision making model which relies on multiple sources of information before committing a vertical handover or otherwise. The foremost importance of any such decision is network availability. Second important information set comprises of the application specific preferences that help in short-listing the available networks to those which provide near application specific requirements.

Other factors that can considerably improve handover efficiency include the possible cell-stay-time and user network preferences. It is highly desirable to switch to a link that has longer range as this can reduce handover frequency. Similarly user may have network preferences which should contribute in handover decision.

This paper discusses vertical handover issues under proposed decision model with Wi-Fi and GPRS data networks. Rest of this paper is organized as follows. Section II presents related work followed by the proposed scheme architecture, decision model and analysis which is given in Section III. Section IV presents simulation setup and result. Conclusion and future work are given in section V.

2. Related work

A vertical handover decision algorithm has been proposed by *Chung-Pyo Hong et al.* in [4]. The algorithm primarily places handover decision at application layer and the algorithm adopts as per application requirement changes. Firstly there is an application manager which abstracts and conceptualizes the application profile that reduces decision to a restricted set of possibilities. The vertical handover decision manager takes the abstracted profile and then the vertical handover decision algorithm is executed to choose a proper network interface. The decision manager creates normalized factors from the profiles and updates them regularly. The decision manager is constantly attempting to find the compatible network interfaces. The session with current network is still maintained and the new network interfaces are verified in dwelling time. The dwelling time is selected to be 60 seconds. When a certain network is said to be steady and stable, then the handover decision is made by decision manager.

W. Zhang in [5] has proposed vertical handover decision devised as a fuzzy Multiple Attribute Decision Making (MADM) problem. MADM first converts a fuzzy data into real number and then rank the contending network according to certain parameters. Two MADM methods are being proposed which are Simple Additive Weighing (SAW) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). In SAW, the score of a single network is acquired by adding the normalized contributions for each metric which is multiplied by weight assigned from another metric. In TOPSIS, the network is selected which is somewhat close to desired situation. . The best values are put in each metric for the ideal cases.

Fang Zhu and Janise McNair have proposed a vertical handover decision algorithm based on policy-based networking architecture [3]. The two main elements for policy control is the policy enforcement point (PEP) and the policy decision point (PDP). Policy decision point's main role is to make the policy decisions from the policies extracted from the policy database. The PDP can also be enhanced for further operations like user authentication, accounting etc. PEP runs on a policy aware network node and its main duty is to fetch the policies for the handover from the PDP and enforce it. The policy database has the metrics information suitable in a vertical handover decision.

3. Cross-layer Vertical Handover Scheme

The proposed scheme CVH, although is independent of wireless link technologies, but for experimental purposes has been devised around two major technologies namely Wi-Max and GSM/GPRS. Main advantage of using these long range technologies roots back into their common characteristics of large cell size and space independence. Further these technologies have larger overlapped region which can be highly useful for stability of decision model in fast mobility scenario. The proposed handover decision has been devised as a match-maker between the gross applications demand and available connectivity resources of each network. Link layer can provide useful triggers that invoke decision model to take perform processing required for proper disbursement of the event. These triggers are not consistent in different link layer technologies but Media Independent Handover (MIH) group of MIPSHOP has worked on their unified interface irrespective of link technologies [9].

Mobile Wi-Max as defined in [7] can perform handover on either Break-Before Make (BBM) or Make-Before Break (MBB) configuration. Mobile Wi-MAX by default incorporates a BBM approach of Hard Handover. This approach may introduce long delays unacceptable for real time applications. Macro Diversity Handover (MDHO) and Fast Base Station Switching (FBSS) are alternatives for MBB approach. In MDHO an MS can communicate with all neighboring BSs in a pre-handover negotiation through scanning process [7]. In FBSS all neighboring BSs should be using same frequency and user contexts, when an MS needs to change its current BS, it needs to choose an anchor BS from the set and continue communication.

GSM/GPRS overlay network uses soft-state management for decision of handover execution [2]. The internal location management (LM) and subsequently location update (LU) procedure of GSM helps in achieving an optimized network initiated handover, but lacks coordination with other technologies. This can be achieved through adding mobile initiated-handover service in GSM.

Normally the MAC layer handover operation in the 802.16e standard may take around 70 mSec where as GPRS handover completion may take longer time due to its overlay operation [2]. On the basis of above mentioned facts proposed scheme architecture is described in the following sub-section.

1.1 Architecture

The architecture of proposed CVH scheme is shown in Figure 1. This decision architecture is based on four main information resources namely network layer triggers (NLT), cumulative application requirements (CARs), network specific preferences (NSP), and user and location profiles (ULP). The link layer handover management works in collaboration with network triggers [8] which play a primarily role in providing information about the network conditions related to service availability and its signal quality and related issues. MIH group of MIPSHOP has provided basic specification for such mobility management layer [9]. The triggers have been unified to avoid any inconsistency in meaning of such events. These triggers include link going down (LGD), new link detected (NLD), link quality down (LQD), Link etc.

The core decision model that supersedes above link layer shim module is shown in gray in Figure 1. There are four monitoring modules which operate in background and keep track of there respective sensor. Dynamic Demand Monitor (DDM) keeps up-to-date state of data-rate and quality of service requirements of all running applications. Network profile monitor (NPM) reports about the most favorable network at present on the basis of stored network preferences by the user. Due to static nature of this information its priority in the ultimate decision is low. User profile monitor has highest to harvest any "out of blue" incentive or user specific preference at a given time and date. The update process of these profiles is kept highly agile for optimized handover decision. Lower layer triggers monitoring (LLTM) module provide the information about the dynamic changes at link layer and relies on the reporting of these event to the upper layer by mobile TCP/IP layer. Match-Maker takes input from the above mentioned four components and converts them into two 16 bit number numbers. One number is generated from the upper layer monitors including DDM, NPM, and UPM where as other number is generated from each of the link layer technologies which in our case are GSM/GPRS and Wi-Max. The better match is indicated to the Handover Executer (HE) which maintains soft-state and performs handover execution if decision model supported for it.

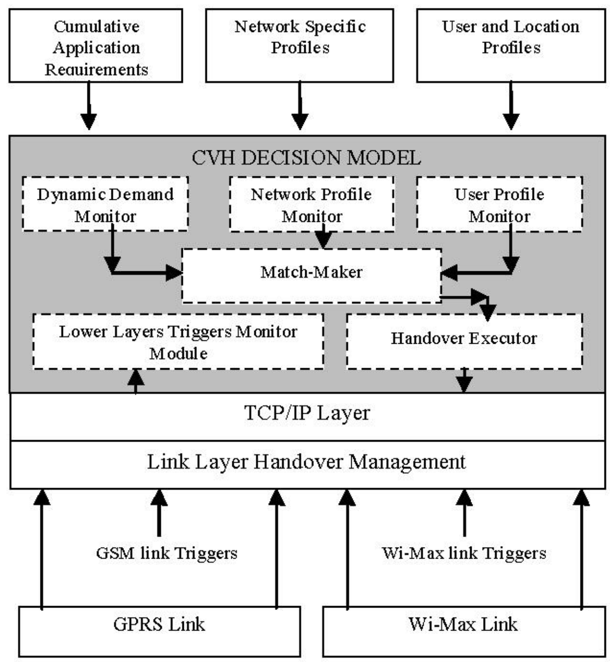

Figure 1: Architectural view of Cross-layer Vertical Handover scheme

1.2 Decision Model

Decision process receives information from multiple sources of information as discussed in the previous sub-section. Figure 2 shows such decision making. Match-Making decision model activates on every link-layer trigger and evaluates current connectivity requirements with available network resources using the information stored in soft-states It is assumes that the two technologies have sufficiently complete infrastructure to ensure availability of at-least one link if not both. Cumulative applications requirement are grouped into a unified system requirement at a specific time and are categorized in eight possible groups as depicted in Table 1. This explicitly describes the system level data rate and QoS requirement for all the applications currently in execution. There may be certain anomaly conditions such as different applications may not be grouped together because of different QoS attributes. This problem may be handled with a complex structure of decision but to keep the task simple and reduce processing overhead this has been grouped to higher grade service if available. This means that if one application requires 128kbps variable delay and another requires 84kbps constant delay service then 256kbps constant rate shall be selected if available.

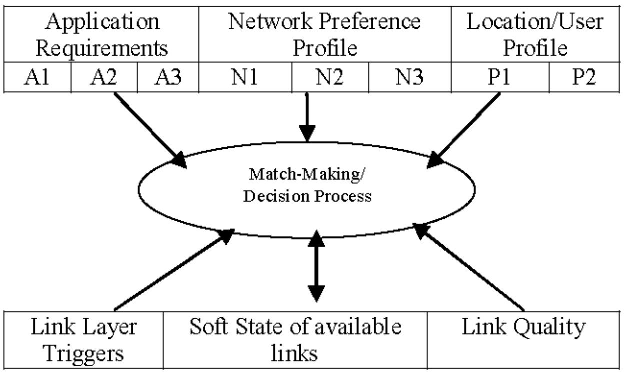

Figure 2: A decision model used for vertical handover decision

Network specific profile is based on some preferred and favorable network services which are primarily activated on specific hours of the day. This is shown in Table 2. This profile can only contribute in the presence of a desired service level available at either networks or the one that has favorable offer.

Table 1: Cumulative Application Requirements grouping

Data Rate / QoS Attributes	A1	A2	A3
64 Kbps / Variable delay	0	0	0
128 Kbps / Variable delay	0	0	1
256 Kbps /Variable delay	0	1	0
512 Kbps / Variable delay	0	1	1
64 Kbps / Constant delay	1	0	0
128 Kbps / Constant delay	1	0	1
256 Kbps /Constant delay	1	1	0
512 Kbps / Constant delay	1	1	1

This table is easily scalable and can accommodate more networks within three bit space by increasing the time frame of every preference. In case it has to be reduced then there are two options. It can be either reduced to variable size time frames such as 2 frames for 2 hours slot and then a single slot of 20 hours. This choice seems more realistic as the favorable conditions on network generally available for lesser time. The other option needs increasing of the decision vector bit to next level. In case 4 bits and more are used more such preferences can be accommodated.

Table 2: Network specific profiles for Cross-layer Vertical Handover decision

Network Preference /Hour of day	N1	N2	N3
Network 1 (0000-0600)	0	0	0
Network 1 (0006-1200)	0	0	1
Network 1 (0012-1800)	0	1	0
Network 1 (1800-0000)	0	1	1
Network 2 (0000-0600)	1	0	0
Network 2 (0006-1200)	1	0	1
Network 2 (0012-1800)	1	1	0
Network 2 (1800-0000)	1	1	1

Location and user profiles provide information about locations where user may be relatively less mobile but may still like forced vertical; handover due to favorable location. For example the office environment or home may provide specific advantages which may overrule any other preference.

The Cross-layer Vertical Handover procedure makes simple comparisons of the accumulated information at different source and makes a handover decision as per decision hierarchy. In this decision hierarchy the link layer information has been given primary status because of it essential requirement. Rest of the decision is based on the location and user profiles first, and then network profile and finally application requirements. Due to only bit comparison process, nominal processing overhead becomes prime advantage that helps in reducing the gap between detecting a possible handover event and executing it.

4. Simulation Results

The proposed scheme has been tested in the ns-2 simulation environment. The decision model is implemented as an application module. Figure 3 presents end-to-end throughput of TCP session between a MS and correspondent Node (MN). The plot indicates a visible performance gain in terms of throughput with significant increase. The more important aspect of this result is the constant rate of data transfer which is prime requirement for seamless mobility. The absence of congestion control behavior is due to the single traffic source resulting in a stable transfer rate through TCP Vegas. Figure 4 presents the handover delay associated with and without CVH scheme. This delay graph indicates a slight declining trend in case of CVH which is desirable for the faster handover. Further the delay remains stable throughout the simulation run which is an indication of robustness of proposed scheme. Figure 5 is a plot of average delay of handover operation under the presence of multiple MS in a cell. The mobility pattern in the simulation was kept random with the arrangement of a specific number of MS present in a cell. Their handover time may not be same but the overall processing load of multiple MS at the access router reduces the performance with respect to the handover delay. Seeing this result from a different perspective, the scheme highlights its scalability feature as the increase in the delay is much lesser as compared to the increase in load of handling multiple sessions and MS at the access router (AR).

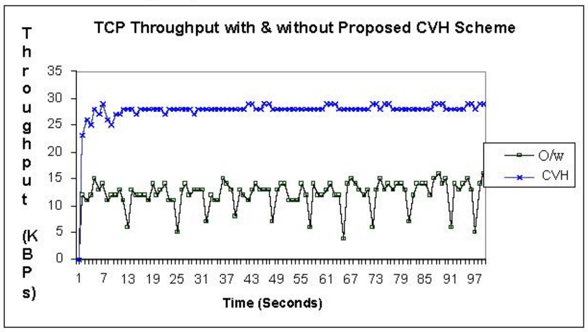

Figure 3: Plot of the TCP throughput with and without CVH scheme

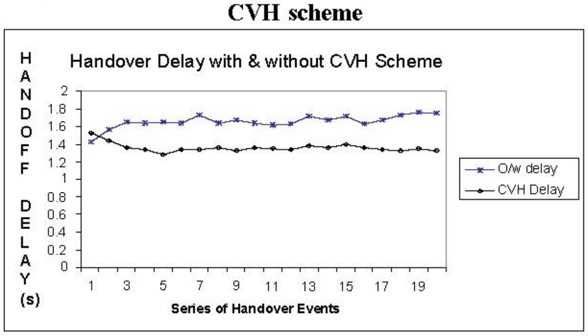

Figure 4: Comparison of handover delay with and without CVH scheme

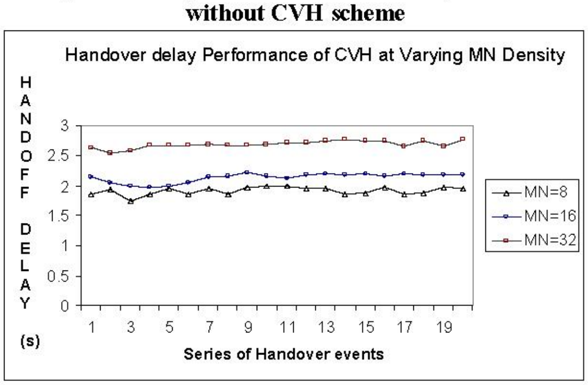

Figure 5: Handover delay performance of CVH under varying load of Mobile Nodes

5. Conclusion

In this paper a simple vertical handover scheme Cross-layer Vertical Handover has been presented which gathers handover related information from multi-layer and make a optimal decision. This reduces the handover complexity from the order of exponential increase with each added argument, to a relatively linear operator by divide and conquer rule. The decision model is simple enough that it does not put major constraint on the computing resources available in an MS. This scheme acts more like a control tap for the fine tuning of handover operation under the provision of multiple network services in a heterogeneous environment. Simulation result indicates that the proposed scheme can be useful in reducing vertical handover frequency which may be higher otherwise and may undergo oscillations due the dynamic nature of wireless signal quality and strength. In future more wireless technologies shall be integrated under this scheme to evolve a comprehensive vertical handover solution.

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