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A Survey on Delay in Vertical Handoff in Heterogeneous Wireless Networks

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***Abstract*— The importance of wireless networks is increasing day by day throughout the world due to cellular and broadband technologies. As a result everyone around the world would like to be connected seamlessly anytime anywhere through the best network. The Fourth Generation wireless system must have the capability to provide high data transfer rates, quality of services and seamless mobility. As there are large varieties of heterogeneous networks in 4G, the users for variety of applications would like to utilize heterogeneous networks on the basis of their preferences such as real time, high availability and high bandwidth. A Seamless vertical handoff is necessary when connections have to switch between heterogeneous wireless networks for performance and high availability reasons. In this survey paper, we explore the current Vertical handoff delay problems. The aim of this work is to identify all potential problems for the delay and propose effective solutions for them.**

Keywords*— *handoff; vertical handoff (VHO); access point (AP); wireless local area networks (Wireless LAN), STA (station).

I. INTRODUCTION

Mobility is the important feature of wireless communication systems and is achieved by handoff mechanisms. The process of changing the channel while session is in progress is called handoff. In 4G networks, handoff is classified into Horizontal and Vertical handoff.

A vertical handoff occurs between two network (e.g., between 3G and 4G networks) access points which are using different network connection technologies, usually to support node mobility in a way that is completely transparent to end user application. For example, a well-equipped laptop might be able to use both a high speed wireless LAN and a cellular technology for Internet access. Wireless LAN connections usually provide higher speeds, higher bandwidth, and while cellular technologies generally provide more ubiquitous coverage. Thus the laptop user might use a Wireless LAN connection whenever it is available, and 'fall over' to a cellular connection when the wireless LAN is unavailable. Vertical handoffs refer to the automatic fall over from one technology to another in order to maintain communication.

Handoff management controls the change of an access point (AP) in order to maintain the connection with the moving device during the active data transmission. The problem is worsened by the presence of APs adopting different technologies.

The vertical handoff process in heterogeneous wireless networks involves three main phases, namely system discovery, vertical handoff decision, and VHO execution. During the first phase, the mobile terminal determines which networks can be used and networks may also advertise the supported data rates and Quality of Service (QoS) parameters. In second phase, the mobile terminal determines whether the connections should continue using the current network or be switched to another network. The decision may depend on various parameters including the type of the application (e.g., streaming, conversational), minimum bandwidth and delay required by the application, distance, transmit power, access cost, and the user's preferences. During the third phase, the connections in the mobile terminal are re-routed from the existing network to the new network in a seamless manner. Authorization, authentication, and transfer of a user's context information are also included in this phase.

In heterogeneous wireless networks handoff of calls between two Base Stations (BSs) is encountered frequently. During the process of handoffs delay can occur, this delay is known as handoff latency. A good handoff decision model of wireless networks should minimize Handoff latency factor. Many handoff decision models have tried to minimize the handoff latency factor in their handoff decision models. Handoff Latencies affect the quality of service of many applications of mobile users, therefore it is essential to consider handoff latency while designing any handoff technique.

In this survey paper we focus on the handoff latency, the reasons for the handoff delay in current handoff protocols. This will guide us to design better solution to reduce the handoff delay.

II. SCOPE OF WORK

Delay in the vertical handoff in heterogeneous network like 4G are classified into following

1. Probe delay
2. Authentication delay
3. Decision delay
4. Re-association delay

Probe delay occurs due to scanning the wireless networks in the current area of the user. This delay can only be reduced by advancement in hardware technologies.

Authentication delay refers to the delay in establishing the trust between the user and the target network before handoff. Without authentication the network or user may be on attack risk so the authentication process cannot be bypassed.

Decision delay refers to the delay in choosing of a target network based on quality parameters. The choosing of network should be done in such a way to reduce further handoff delay and QOS is not sacrificed.

Re-association delay is the delay in actual handoff. After selecting a suitable AP, the old station needs to associate with the new AP. The association process allows the new AP to allocate resources for the old station. So in transferring all old sessions to the new AP delay occurs called Re-association delay.

The delay of probing and re-association is affected by the choice of access point. By selecting the suitable AP based on the multi criteria parameters like distance, cost, load of the AP, power consumption and bandwidth the delay will have big impact. So our research work will also focus on selection of AP with assistance of multi criteria parameters. In this survey work, we focus more on last three delays and restrict the scope to exploring the current works in handoff and their results on these three delays.

III. SURVEY: DELAY IN VERTICAL HANDOFF

A. Probe delay

Probe delay contributes 90% to the total handoff latency and the latency varies depending on the environment, hardware capabilities and parameter selection [1]. A selective channel scanning method using neighbor graph (NG) approach [2] was proposed to reduce the probe delay. This technique was first introduced by Arunesh et al. [3], uses the topological information on APs to reduce the number of channels to be scanned. A more aggressive approach to reduce probe delays proposed by Vladimir Brik et al. [4], used two radio interfaces to perform active scanning and data communication simultaneously. The primary interface was used for data transmission while the secondary was used for probing neighboring APs. The roles of both interfaces were swapped once the secondary interface has completed its association process.

A similar approach called the make-before-break algorithm was proposed [5] in which the STA uses two radio cards to gather neighboring information through periodic probing. Similarly, the functions of the two radio cards were switched for data communication and probing.

This concept was extended (two radio card concept) to eliminate the probe delay and an approach called Shared Beacon Channel was proposed [6]. A STA is equipped with two radio cards, one for data communication and another one for listening to a shared beacon channel to determine the next AP based on its handoff policy. The feasibility of using two radio receivers remains an issue to be questioned in terms of level of interference, power consumption and cost of development.

A more practical handoff mechanism called SyncScan making use of scanning time synchronization was proposed [7]. In this mechanism a special type of beacon frame was used to be periodically broadcast by the APs in order to identify themselves to the STAs in range and to synchronize the service state information with all the currently associated STAs. On each channel the timing of beacon broadcast is synchronized between the STAs and the APs so that the STAs can efficiently identify all the neighboring APs by regularly switching to each channel; this method minimizes the time it losses communication with its own AP.

A similar approach that uses the concept of continuous monitoring of neighboring APs [8] was proposed, in which the STA driver continuously monitors the link quality of all the APs operating on the STA's current channel, as well as all the neighboring APs operating on its overlapping channel through beacon signal strength measurement. Also the driver source code is modified to monitor APs operating on overlapping channels.

The work of [8] was extended to present another trigger method using Proactive Scan [9]. The main idea of this work was to decouple the time consuming channel scanning from the actual handoff, and to initiate the scanning process early and in a way that allows ongoing traffic. In addition to that, Proactive Scan considers both uplinks and downlink quality before handoff is triggered.

B. Authentication delay

A broker-based architecture was proposed for integrated heterogeneous networks [10], which presented an extended handoff keying to reduce the user authentication delay. Also other techniques such as proactive configuration, data buffering and controlled forwarding were used to reduce the handoff delay and ensure seamless transitions. But the work is specific to 802.11 networks and its applicability to other networks is doubtful.

A couple of re-authentication protocols were proposed to reduce re-authentication delays during UMTS-WLAN VHs (Vertical Handoffs) compared to existing protocols by substantially reducing message signaling [11]. But this work requires the usage of lot many keys for each user. So scalability for large user base becomes a problem.

The EAP-TLS protocol for pre-authentication between WiFi and WiMAX hybrid networks [12] reduced the network delay considerably but used the public key infrastructure for porting with other networks.

The Seamless vertical handoff solution for real-time data transfer with fast authentication [13] decreased the number of authentication messages by combining the authentication with handoff messages but the assumption made is there must not be any packet loss. The authentication process fails in case of packet loss so extending the solution to 4G networks is difficult.

The signaling load, authentication procedures and compatibility of vertical handoff in the EPS architecture networks [14] were assessed. This work cannot be applied in real world scenarios in 4G networks because of walk model and authentication mechanism proposed in this work.

A vertical handoff scheme based on reordering of L2 and L3 signaling messages & also combining of L2 and L3 signaling messages [15] was proposed. This scheme will result in getting shorter vertical handoff latency. This cross layer optimization was also tested for WiMAX and 3G network handoffs. But this scheme does not address authentication, it address only the latency in packet transfers.

A mobile based proactive handoff mechanism [16] was proposed to reduce the handoff latency. All connection parameters were reserved in advance to enable fast handoff, but it is practically impossible in real 4G networks to implement these assumptions.

The seamless authentication protocols (SAPs) for vertical handoff [17] in wireless heterogeneous networks was proposed to reduce authentication delay. Three versions of SAP protocols were proposed in this paper work. The protocols were secure against spoofing & crypto analysis attack with fast handoff. The key distribution mechanism in this work has huge overhead and the work is not secure against insider attacks.

A novel mobility management solution for vertical handoff in WWAN and WLAN networks was proposed [18]. MAC sensing, FFT detection, and adaptive threshold configuration algorithms were proposed to significantly reduce the hand-off rate and ping-pong effect. But the approach was not able to address the cross domain problems in the handoff. The work was more focused on reducing the re-association delay but no solutions were given for authentication delay.

An asymmetric cryptographic mechanism for authentication in GSM, GPRS and UMTS networks [19] was proposed, but the mechanism works poorly for vertical handoffs with bigger key exchange overhead.

C. Decision delay

An algorithm for network selection was proposed based on averaged received signal strength, outage probability and distance [20]. The proposed algorithm comprises of two stages. In first stage, overlapping region is identified through distance estimation. Network selection algorithm based on averaged received signal strength plus outage is invoked in second stage to select the optimum network. In the paper it is been shown that the proposed algorithm offers 68% improved performance in terms of network selection rate.

Access Point selection mechanisms were proposed for load balancing among APs [21], [22]. The proposed algorithms considered RSSI (Received Signal Strength Indicator) and the number of STAs connecting to an AP, and also took into account only BE (Best Effort) traffic. But, in 802.11e WLAN networks, traffic types and their traffic loads should be considered rather than the number of STAs. Therefore, it is difficult to apply their algorithms to IEEE802.11e WLANs. Moreover, they assumed that STAs could use the same transmission rate even when they are connected to APs that are very far from it. However, in general, if a STA communicates with an AP that is far from it, it needs to use low transmission rate. Therefore, taking into account only the number of STAs for load balancing will result in increased number of STAs that use low transmission rate, radio resource is inefficiently utilized and throughput of WLAN networks declines.

D. Re-association delay

Previous analysis on IEEE 802.11 MAC layer handoff shows that re-association delay contributes 15.37 ms to the overall handoff delay [1]. To reduce the re-association delay when IAPP (Inter Access Protocol Point) is applied, an approach called context caching by using neighbor graph (NG) was proposed [3]. The major contribution is to propagate the STA security contexts proactively to the next potential APs in order to eliminate the IAPP latency during re-association.

Previous works that focus on reducing the overall handoff delay are generally based on context transfer mechanism , key objective being to establish and keep service state information which is essential to process and forward packets in a way that suits specific service requirement.

The idea of context transfer was used and a proactive scheme [23] was proposed to estimate the best time to transfer context information associated with the STA. In this scheme, the handoff is triggered at a planned time to avoid unnecessary handoff.

The same concept was used and an approach called Mobile AP to determine the best time to trigger the handoff was presented [24]. In this scheme, the handoff decision is made by the AP instead of STA. Each AP collects the STA-AP network connection quality information and reports the Received Signal Strength Indicator (RSSI) information from all overheard STA data frames. Then the AP selectively broadcast its local STA-AP connection and link quality information of both the associated and not associated STAs. A handoff decision is made by an AP if another AP reports the best link quality among all the APs. Once the old AP initiates handoff, the old AP transfers the STA-AP context information to the new AP using Mobile AP protocol (similar to IAPP).

IV. OPEN ISSUES

As we see the survey we notice following problems in the solutions

- Most solutions are specific for particular network combination and not generic to all networks.
- The key distribution mechanism and authentication procedures are not secure against all kinds of attacks like spoofing, cryptanalysis and insider attacks.
- The solutions are not fault tolerant in case of packet loss or sub system failures.
- Many solutions don’t address re-association delay and mechanism to reduce it.
- Frequent rekeying adding to scalability problems in case of bigger 4G networks.

This open issue motivates us to propose an efficient solution addressing this concern.

V. Conclusion and Enhancements

The paper summarizes the current works in the vertical handoff for reducing the handoff latency. We explored the demerits in the current solutions and identified the open areas for further research. Our further work will implement concrete solutions for these open problems to enable seamless handoff with least handoff latency.

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