PREDICTIVE CONTEXT TRANSFER PROTOCOL FOR MOBILITY MANAGEMENT IN CENTRALIZED WIRELESS LOCAL AREA NETWORK

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To my beloved mother and father,

To my lecture and supervisor, for their guidance and encouragement,

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ABSTRACT

In secured large scale Wireless Local Area Network, Context Transfer (CT) technique has been proposed to reduce the main handover latency component in a secured environment, which is 802.1x authentication phase. In order to achieve seamless handover, this work will use the CT technique to transfer the Pairwise Master Key (PMK) of clients to the new Access Point (AP) before handover process. However the drawback of using CT method is that the AP will receive the context cache even if a mobile user is not roaming, resulting in high memory usage in the AP. In this thesis, a context aware handover management technique is introduced to predict the handover initiation for mobile user in an indoor environment. The predictive technique includes a method called Received Signal Strength (RSS) transition pattern and client's Moving Weight (MW) to detect handover initialisation for mobile users. This technique will distribute the context cache only when it detects that mobile user is leaving the current AP. Early RSS transition pattern is an enhanced technique that collects RSS data before client reaches the handover threshold and makes the handover decision. Client's MW technique is able to predict the movement status of mobile user whether it is static or moving within the network coverage. This proposed method is called Predictive Context Transfer (PCT) technique that will be implemented in the Access Controller. PCT is able to reduce the re-authentication latency during the handover process up to 80% and below than 150ms which is the requirement of VoIP standard. Moreover, PCT for handover initialisation using the client's MW is able to prevent unnecessary handover process and predict when the client is leaving the current network during the handover process.

ABSTRAK

Bagi Rangkaian Kawasan Tempatan Tanpa Wayar yang bersekuriti dan berskala besar, teknik Pemindahan Konteks (CT) telah diperkenalkan untuk mengurangkan komponen utama dalam pemindahan talian komunikasi iaitu fasa pengesahan 802.1x. Bagi mencapai pemindahan talian komunikasi yang lancar, teknik CT akan memindahkan Pasangan Kunci Master (PMK) pelanggan kepada AP yang baru sebelum proses pemindahan komunikasi. Walau bagaimanapun, kelemahan menggunakan kaedah CT ialah AP akan menerima konteks informasi walaupun pengguna mudah alih tidak bergerak yang akan mengakibatkan penggunaan memori yang tinggi oleh AP. Dalam tesis ini, teknik penyerahan konteks secara sedar untuk pengurusan peralihan komunikasi telah diperkenalkan untuk meramalkan penyerahan memulakan peralihan komunikasi terutamanya di dalam persekitaran tertutup. Teknik ramalan peralihan komunikasi termasuk kaedah yang dipanggil corak peralihan Kekuatan Isyarat yang Diterima (RSS) dan Pemberat Pergerakan (MW) Pelanggan untuk mengesan permulaan penyerahan untuk pelanggan-pengguna telefon bimbit. Teknik ini hanya akan mengedarkan konteks informasi apabila mengesan individu meninggalkan AP. Corak peralihan RSS awal adalah teknik yang dipertingkatkan untuk mengumpul data RSS sebelum pelanggan mencapai paras tententu untuk membuat keputusan penyerahan. Teknik MW pelanggan dapat meramalkan status gerakan pengguna mudah alih yang statik atau bergerak dalam liputan rangkaian. Kaedah yang dicadangkan dipanggil teknik Ramalan Pemindahan Konteks (PCT) akan diprogram dalam Pengawal Akses. PCT mampu mengurangkan 80% masa yang diambil semasa proses pemindahan talian dan di bawah tempoh 150ms terumatanya bagi aplikasi seperti VoIP. Selain itu, PCT untuk pengawalan penyerahan menggunakan MW pelanggan dapat mengelakkan proses penyerahan yang tidak diperlukan dan meramal apabila pelanggan bergerak meninggalkan rangkaian semasa proses penyerahan.

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LIST OF ABBREVIATIONS

AA	-	Authenticator Address
AAA	-	Authentication, Authorization and Accounting
AC	-	Access Controller
AKM	-	Authentication and Key Management
AKMP	-	Authentication and Key Management Protocol
ANounce	-	Authenticator Nounce
ARP	-	Address Resolution Protocol
AP	-	Access Point
API	-	Application Programming Interface
AS	-	Authentication Server
ASST	-	Application Signal Strength
BSS	-	Basic Service Set
CAPWAP	-	Control And Provisioning Wireless Access Point
CI	-	Confidence Interval
CT	-	Context Transfer
DHCP	-	Dynamic Host Configuration Protocol
DNS	-	Domain Name System
EAP	-	Extensible Authentication Protocol
EAP-AKA	-	EAP-Authentication and Key Agreement
EAP-POTP	-	EAP-Protected One-Time Password
EAP-SIM	-	EAP-Subscriber Identify Module
EAP-TLS	-	EAP-Transport Layer Security
EAP-TTLS	-	EAP-Tunneled Transport Layer Security
EAPOL	-	Extensible Authentication Protocol Over LANs
GMK	-	Group Master Key
GTK	-	Group Temporal Key
GTKSA	-	Group Temporal key Security Association
GUI	-	Graphical User Interface

IAPP	-	Inter-Access Point Protocol
IBSS	-	Independent Basic Service Set
ICMP	-	Internet Control Message Protocol
IEEE	-	Institute of Electrical and Electronics Engineers
IETF	-	Internet Engineering Task Force
ITU	-	International Telecommunication Union
ITU-T	-	ITU-Telecommunication Standardization Sector
KCK	-	EAPOL-Key Confirmation Key
KEK	-	EAPOL-Key Encryption Key
LAN	-	Local Area Network
LEAP	-	Lightweight Extensible Protocol
LS	-	Least Square
LTE	-	Long Term Evolution
LWAPP	-	LightWeight Access Point Protocol
MAC	-	Medium Access Control
MI	-	Moving In
MIC	-	Message Integrity Code
MN	-	Mobile Node
MO	-	Moving Out
MU	-	Mobile User
MW	-	Moving Weight
MWD	-	Moving Weight Discovery
PCT	-	Predictive Context Transfer
PDA	-	Personal Digital Assistant
PMK	-	Pairwise Master Key
PMKID	-	Pairwise Master Key Identifier
PMKSA	-	Pairwise Master Key Security Association
PRF	-	Pseudo-Random Function
PSK	-	Pre-Shared Key
PTK	-	Pairwise Transient Key
PTKSA	-	Pairwise Transient Key Security Association
QoS	-	Quality of Service
RADIUS	-	Remote Authentication Dial In User Service
RFC	-	Request For Comments

RSN	-	Robust Security Network
RSNA	-	Robust Security Network Association
RSS	-	Received Signal Strength
RSSI	-	Received Signal Strength Indicator
RTA	-	Real Time Application
SNounce	-	Supplicant Nounce
SPA	-	Supplicant Address
STA	-	associated Station
TCP	-	Transmission Control protocol
TKIP	-	Temporal Key Integrity Protocol
UAM	-	Universal Access Method
UDP	-	User Datagram Protocol
UMTS	-	Universal Mobile Telecommunications System
VoIP	-	Voice over IP
WEP	-	Wired Equivalent Privacy
Wi-Fi	-	mechanism for wirelessly connecting electronic devices
WiMax	-	Worldwide interoperability for Microwave access
WLAN	-	Wireless Local Area Network
WLC	-	Wireless LAN Controller
WPA	-	Wi-Fi Protected Access
WTP	-	Wireless Termination Point
WWW	-	World Wide Web

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LIST OF SYMBOLS

$t_{handover}$	-	Handover latency
t_{scan}	-	Scanning latency
$t_{re\text{-}authentication}$	-	Re-authentication latency
$t_{authentication}$	-	Authentication phase latency
$t_{association}$	-	Association phase latency
$t_{802.1x\ authentication}$	-	802.1x authentication latency
$t_{4\text{-}way\ handshake}$	-	4-way handshake latency
s_i	-	Measured strength of client's signal strength
t_i	-	Time for data sampling of client's signal strength
t_{MW}	-	Time for collected client's RSS data for Moving Weight
θ	-	Slope of the least square algorithm of the collected line
σ	-	Intersection point of the least square and the y-axis
T_H	-	Handover threshold
MW_I	-	Client's MW for moving in
MW_O	-	Client's MW for moving out

CHAPTER 1

INTRODUCTION

1.1. Introduction

In recent years, individual have been attracted to wireless-based communication since wireless supports mobility during information exchanged while changing networks at higher speed. Nowadays, technologies in wireless communications provide users many alternatives to be connected to the Internet, such as WiMAX, Wi-Fi, Long Term Evaluation (LTE) and cellular network. Most individual today carries with them multiple numbers of mobile devices[1] (i.e. smart phones, laptops and tablet PCs) that can be connected to a network. As the individuals move from one network to another network, they expect their services to be seamless with less interruption. This is illustrated in Figure1.1.

For security in Wi-Fi, most of the network users use secure authentication mechanisms such as pre-shared key (PSK) authentication system designed for small scale network (i.e. restaurant, home, shop) or 802.1x authentication designed system for large scale network (i.e. corporate company, factory, university). For enterprise network, this has becomes a challenge for Wi-Fi network planners because enterprise Wi-Fi deployment depends on the extremely capabilities of the Wi-Fi Access Points (APs) alone. Moreover, secure communication is important for enterprise network to protect their own network from intruders.

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[1] In this thesis, mobile device will be use interchange used with client, mobile user, mobile terminal and station.

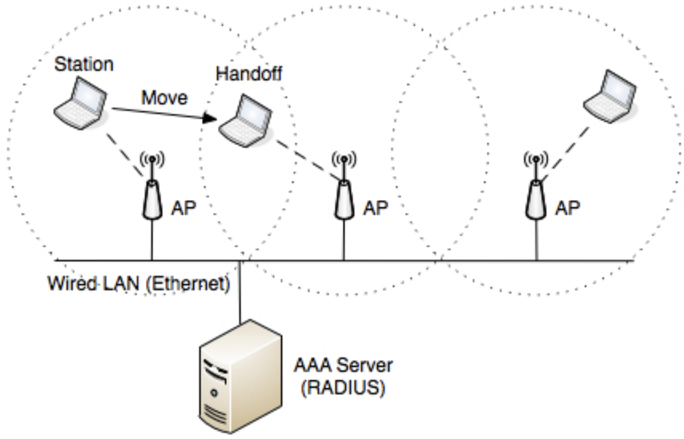

Figure 1.1: Typical topology of a WLAN

In order to deploy enterprise large scale Wi-Fi networks, planners have to deploy several APs that are connected to the Internet backbone. All the deployed APs do not communicate with each other to share mobile terminal's information such as registration key, IP address and MAC address[2]. This results in spotted Wi-Fi coverage where an entire area is covered with collaborative deployment of over-lapped APs without any intelligence. As the owner of the mobile devices walks around enterprise, the mobile devices are forced to roam from the coverage area of one AP to another. During roaming, users will experience disruption in their services especially for Real-Time Applications (RTAs) such as Voice over Internet Protocol (VoIP), video teleconferencing, video streaming and online gaming. VoIP is considered as the most time constraints application, compared to others RTAs with handover latency below 150ms [1].

In order to achieve seamless handover, this project will use the Context Transfer[3] (CT) method to transfer the Pairwise Master Key (PMK) mobile users to the new AP before the handover process [2]. This method is expected to reduce 802.1x re-authentication latency during the handover process. Furthermore, to achieve mobile user roaming seamlessly in secured large scale Wireless Local Area Networks (WLAN), the context was proposed to reduce the main handover latency component in a secured environment, which is in the 802.1x authentication phase.

[2] Unique identifier registered to Network Interfaces Card (NIC) for communications.
[3] Context Transfer is a technique for fast re-authentication latency to reduce the re-authentication latency during roaming by transferring the key to other APs

However, in existing CT methods, the AP receives the context cache even when the mobile users do not roam, resulting in high memory usage in the APs. The increasing consumption in the AP's memory decreases the capacity and the efficiency of the network performance.

1.2. Problem Statement

Roaming results in mobile terminals abruptly disconnecting from the previous AP to reconnect to a new AP, which causes higher handover latency. Higher handover latency causes the service interruption from user that uses RTA. However, to connect to a new AP, mobile users need to scan for the new AP and re-authenticate with new AP. In the re-authentication operation, there are three phases, namely authentication and association phase, 802.1x authentication phase and 4-way handshake phase. This high latency of the re-authentication phase will cause the mobile device to take a longer time to reconnect to the new AP and causes higher handover latency and increase packet loss that will affect the performance of RTA.

Context transfer method is used to reduce latency in 802.1x authentication phases because re-authentication has high latency compared to other phases [3]. However, in existing context transfer method, the AP receives the context cache even if the mobile user does not roam, resulting in high memory usage in the AP and decreases the efficiency of the network performance [4].

Handover decision is a method to determine and predict when the mobile user will start to handover later in future. However, in existing handover decision, there is a probability for handover failure and unnecessary handover during roaming in WLAN due to inaccurate prediction and decision [5]. The available existing handover decision using RSS for WLAN is directly adapt from cellular network technique such as handover threshold, averaging and RSS transition pattern technique [6]. The simulation had been done using existing technique for outdoor environment only. The coverage for indoor environment is smaller than outdoor environment requires faster handover decision-making [7].

1.3. Objective of The Research

To address the above challenges in WLAN, this research proposes a new context transfer protocol that will efficiently transfer the context cache between Access Controller (AC) and AP before mobile user handover to new AP. Based on problem statements, the objectives of this study are:

- To develop context aware handover management protocol that predicts mobile users handover in indoor environment.
- To develop predictive algorithm for handover initialization that can reduce unnecessary handover and handover decision-making latency.
- To implement and analyze the performance of proposed protocol in a real experimental enterprise WLAN testbed.

1.4. Scope of The Research

The scope of work for the project is generally the IEEE802.11 using the 802.11n and features in 802.11i. For 802.11 architecture, we will use the centralized architecture using the local MAC in the access points. The testbed consists of access controller, access points and RADIUS server. The WPA2-Enterprise authentication mechanism will be used as the authentication. Extensible Authentication Protocol-Transport Layer Security (EAP-TLS) will be used in the authentication mechanism, as this project will be deployed for secure network in an enterprise environment. In the experiments, it is assumed that the AP's signal has full coverage. Received Signal Strength (RSS) is used as a main component in the handover decision for prediction movement of the mobile user.

This project used the implementation approach for prove of concept. The implementation will be done in PC and laptops installed with *Ubuntu* Operating System (OS). The open source software called *hostapd* is used in the AP and *freeradius* will used in the RADIUS server. In this project AC is installed with

Coova due to its advantages compared with other programs (i.e. open-source, well documented and new compare to other programs). The PC-based AP will use 802.11n WLAN card. All the experiments and the entire setup of this research have been implemented in MIMOS Berhad laboratory. The development of the program will be done only on the network side such as AP and AC without any modification on the mobile users.

1.5. Significance of Project

This research has been conducted to improve the context transfer method in order to increase the efficiency of network performance and improved the accuracy of the handover decision during roaming. Extended literature review has assisted to generate new methods and algorithm in the application on AC. The contribution are being listed below:

- Context aware with handover management
    - Seamless handover has been successfully developed on the enterprise WLAN that allows mobile users moving in secure network environment
    - A new context transfer method called Predictive Context Transfer (PCT) technique that distribute the context cache after predicting the mobile user is leaving the current AP has been developed.
- Enhanced handover initialization with prediction
    - Modifying the prediction of RSS transition pattern and adding the client's Moving Weight (MW) in the handover decision algorithm for PCT have improved existing handover decision using RSS.
- Enhanced performance of real experimental enterprise WLAN testbed
    - Enterprise WLAN with PCT reduces authentication latency and increase performance of handover decision specifically for indoor environment.

1.6. Thesis Outline

This thesis consists five chapters and is organized as follows:

In the chapter 1, we discuss the problem statement, objective of the research, significance of research and scope of this project.

Chapter 2 discuss on the theory and literature reviews of the existing work. This chapter covers the relevant background of understanding WLANs. It discusses on IEEE 802.11 Architecture and IEEE 802.11 Authentication Mechanism especially focuses in 802.1x Authentication. This chapter introduces the challenges and current implementation in reducing the re-authentication latency in secure network. The related works regarding context transfer method and handover decision with RSS discussed in Chapter 2.

Chapter 3 describes the methodology and implementation details of the centralized WLANs. This chapter explains the installation of AP, AC and RADIUS for testbed setup for the project. The flow of the overall project is discussed in this chapter. A graphical user interface (GUI) development for AC also is presented in Chapter 3. The chapter will be discussed on the proposed system design. The framework of PCT is described in this chapter. It includes the main rules in PCT, which are handover threshold, prediction of RSS transition pattern and client's MW.

The results and discussions will be presented in chapter 4. For chapter 4, the importance of context transfer methods is proven with the network performance without PCT and with PCT embedded in the network. The PCT will be compared with an existing method and algorithm for prediction accuracy based on cache hit and false alarm.

Last but not least, chapter 5 discusses the conclusion and summary of this project, along with suggestions for future work that can be done.

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