Seamless VoWLAN Handoff Management based on Estimation of AP Queue Length and Frame Retries

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***Abstract*—Switching a communication path from one Access Point (AP) to another in inter-domain WLANs is a critical challenge for delay-sensitive applications such as Voice over IP (VoIP) because communication quality during handoff (HO) is more likely to be deteriorated. To maintain VoIP quality during HO, we need to solve many problems. In particular, in bi-directional communication such as VoIP, an AP becomes a bottleneck with the increase of VoIP calls. As a result, packets queued in the AP buffer may experience a large queuing delay or packet losses due to buffer overflow, thereby causing the degradation of VoIP quality for the Mobile Nodes (MNs) side. To avoid this degradation, MNs need to appropriately and autonomously execute HO in response to the change in wireless network condition, i.e., the deterioration of wireless link quality and the congestion state at the AP. In this paper, we propose an HO decision strategy estimating AP queue length at an MN and exploiting frame retries to maintain VoIP quality during HO.**

I. Introduction

Wireless LAN (WLAN, IEEE802.11a/b/g) has been the dominant wireless network and is extensively deployed today. Meanwhile, there is a huge demand for Voice over IP (VoIP) service over WLANs. However, delivering VoIP over WLANs (VoWLANs) has many challenges because VoIP is a delay and packet loss sensitive application. In some metropolitan areas, WLANs (WiFi hotspots) have already provided Internet connectivity to many mobile nodes (MNs) everywhere. In such an environment, the MNs are likely to traverse several WLANs with different IP subnets during a VoIP call because the coverage of individual WLAN is relatively small. Consequently, VoWLAN quality could be drastically degraded due to the severe wireless network condition caused by the increase of the number of the MN and the movement of MN. Therefore, to maintain VoWLANs quality, MNs need to appropriately and autonomously execute handoffs (HOs) in response to the wireless network condition.

In a mobile environment, typically, two main factors degrade VoWLAN quality: (1) degradation of wireless link quality and (2) congestion at an access point (AP). First, as an MN freely moves across WLANs, the communication quality degrades due to the fluctuation of wireless link condition. Second, as VoIP is a bi-directional communication, an AP becomes a bottleneck with the increase of VoIP calls. That is, VoIP packets to MNs are liable to experience a large queuing delay or packet loss due to buffer overflow in the AP buffer because each MN and AP has almost the same priority level of frame transmission by following the CSMA/CA scheme. In addition, in multi-rate WLANs, although a rate adaptation function changes transmission rate in response to wireless link condition, low transmission rate occupies more wireless resources than a high transmission rate. Thus, compared with a high transmission rate, a low transmission rate tends to cause a congestion at an AP. Therefore, to maintain VoWLAN quality, we need to develop an HO strategy considering these two factors in WLANs.

So far, many researchers have studied HO strategies. Although most of them focus on the mechanism to switch wireless networks, they do not sufficiently study an HO strategy considering both wireless network condition and characteristics of an application. In a bi-directional real-time communication such as VoIP, packets queued in the AP buffer experience a queuing delay or packet loss, thereby resulting in degradation of VoIP quality for MN. However, a common AP, which has already spread, does not have a mechanism to report the congestion state to MNs. Thus, MNs needs to estimate the occurrence of the congestion at the AP for avoiding degradation of VoIP quality.

In this paper, first, we study a method to estimate AP queue length at an MN side to detect the congestion in a WLAN. Then, we propose a new HO strategy method considering wireless network conditions, i.e., the deterioration of wireless link condition and congestion at the AP. Finally, we show the effectiveness of our proposed method through simulation experiments.

II. Related Work

Many HO decision strategies have been studied for various layers of the protocol stack where network and transport layers are most widely studied. Mobile IP [**?**] is a network layer scheme utilizing and relying on network infrastructures. However, an HO process in Mobile IP takes a significant time period including the period for acquisition of the IP address in a new WLAN and binding update to a Home Agent and a Corresponding Node (CN). On the transport layer, mobile Stream Control Transmission Protocol (mSCTP) [**?**], which is a mobility extension of SCTP, has been proposed. Although mSCTP supports multi-homing and dynamic address reconfiguration for mobility, the issue of the HO decision is not discussed in details. The authors in [**?**] proposed an SCTP based HO scheme for VoIP using a Mean Opinion Score (MOS [**?**]) as an HO decision metric. This HO mechanism

Fig. 1: The Miniature of a Process Control Plant for Industrial Solid Materials

employs a probe message called heartbeat to estimate a Round Trip Time (RTT) and calculates MOS value based on the RTT. However, since upper layer (above layer 3) information such as packet loss, RTT, and MOS indicate end-to-end communication quality, the information is varied due to both the wireless and wired network [**?**]. Therefore, the existing study could execute unnecessary HOs due to some factors in the wired network, such as temporal congestion (not in the wireless network). That is, in a mobile environment, MNs need to promptly and reliably detect wireless link condition by exploiting the lower layer (below layer 2) information. Furthermore, our practical experiments in [**?**] proved that the number of frame retries on the MAC layer has the potential to detect the wireless link degradation during movement because packets over wireless inevitably experience frame retries before being treated as packet loss.

Ref. [**?**] proposed an HO mechanism employing the number of frame retries as an HO decision metric through analytical study. This method, however, only considers the frame retransmission caused by the collision with frames transmitted from other MNs in a non-interference environment. On the other hand, previously, we proposed an HO strategy method considering the number of frame retries on the MAC layer [**?**] [**?**] [**?**]. This strategy employs single-path and multi-path transmission modes to execute soft-HO between two WLANs with different IP subnets. Although our previous method can detect the degradation of wireless link condition due to both movement of MN and radio interference, it cannot detect congestion at a targeted AP. This is because our previous method detects wireless link condition based on only frame retries without considering congestion at the AP. Therefore, in our previous method, an MN could execute an HO to a congested AP, and then VoIP quality would be degraded.