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A simple heuristic for handover decisions in WLANs
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Abstract

This document discusses handover decision criteria for avoiding deterioration in communication quality during WLAN handover, in particular at handover initiation. We first describe problems for handover decision criteria employed by existing mobility management technologies, such as Mobile IP and mSCTP. We then propose the number of frame retransmissions as a simple heuristic for handover decisions and discuss its advantages and disadvantages.

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1. Introduction

Wireless LANs (WLANs) based on the IEEE 802.11 specifications [1] are spreading widely due to their low cost, simplicity of installation and broadband connectivity. WLANs are being set up not only in private spaces such as the home and workplace, but also in public spaces such as waiting areas and coffee shops as hotspots. Thus, WLANs that are independently managed by different organizations are starting to complementarily cover wide areas such an entire city. In the near future, WLANs will continue to spread until they overlap to provide continuous coverage over a wide area, and they will then be the underlying basis of ubiquitous networks.

In ubiquitous networks consisting of WLANs, mobile nodes (MNs) can access the Internet through access points (APs) at any location. MNs are very likely to traverse multiple WLANs divided into different IP subnets during communications, because the coverage of a WLAN is relatively small. As a result, the communication is disconnected due to the change in IP address of the MN required for handover.

To achieve continuous communication during handover, many mobility management schemes such as Mobile IP [2,3], mobile Stream Control Transmission Protocol (mSCTP) [4], and others [5,6,7] have been proposed. These schemes use various movement detection methods for starting the handover process. However, in [8], we showed that these movement detection methods result in the degradation of communication quality at WLAN handover initiation. Furthermore, in ubiquitous networks, as the communication quality is often degraded due to both (1) the MN's movement and (2) radio interference with other WLANs, proposing a handover decision criterion that can detect both (1) and (2) is a critical issue. Thus, the main focus of this article is on handover decision criteria for avoiding degradation in communication quality at handover initiation. We first clarify problems of handover decision criteria arising from existing mobility management technologies, and then propose the number of frame retransmissions on the MAC Layer (Layer 2) as a simple heuristic for handover decisions to realize seamless and efficient WLAN handover.

2. Existing WLAN handover decision criteria

Handover decision criteria used by existing mobility management technologies can be classified according to the information measured on upper/lower layers. (An upper layer is Layer 3 or above, and a lower layer is Layer 2 or below.) In [8], we investigated the impact of existing handover decision criteria on communication quality at handover initiation. In this section, we clarify characteristics of the existing handover decision criteria on upper/lower layers.

2.1 Handover decision criteria on upper layers

Packet loss (including data/signaling packets) and RTT are commonly used as handover decision criteria in existing handover technologies [2,3,6,7,9]. In [8], through simulation experiments, we showed that the communication quality has already been degraded even when an MN starts the handover process just after detecting the occurrence of a packet loss or an increase of RTT. In a WLAN, communication quality is degraded due to deterioration in the wireless link condition even if packet loss does not occur or RTT does not seriously increase. Therefore, these criteria on upper layers cannot detect abrupt fluctuations of wireless link condition reliably and promptly. To avoid degradation of communication quality at handover initiation, it is essential to effectively detect deterioration in the wireless link condition.

2.2 Handover decision criteria on lower layers

Wireless signal strength is usually considered as a handover decision criterion on lower layers [4,10]. Signal strength can provide information about a wireless link condition directly from the Physical Layer. However, properly detecting deterioration in communication quality caused by fluctuations of signal strength is very difficult for an MN, because the signal strength may fluctuate abruptly due to the distance from an AP and any interfering objects located between the MN and the AP.

Furthermore, in ubiquitous networks consisting of WLANs, degradation of communication quality due to radio interference is common. However, MNs cannot detect this type of degradation by assessing the signal strength. Thus, to maintain communication quality during handover, an MN should be able to detect both its own movement and the radio interference.

In addition, if signal strength is used as a handover decision criterion, it is very difficult to set a threshold to start the handover process, because the allowable range of signal strength (Received Signal Strength Indicator: RSSI) depends on each vendor, e.g., Cisco chooses 100 as RSSI-max while the Atheros chipset chooses 60 [10]. Therefore, monitoring signal strength is insufficient to avoid degradation in communication quality at handover initiation.

3. The number of frame retransmissions

As described in Section 2.2, to avoid degradation in communication quality at WLAN handover initiation, a handover decision criterion should reliably and promptly detect degradation of communication quality due to both (1) MN's movement and (2) radio interference. We propose the number of frame retransmissions as a simple heuristic for handover decisions which satisfies these two requirements [8,12].

3.1 Frame retransmission mechanism of IEEE 802.11

We will outline the frame retransmission mechanism of IEEE 802.11. In the IEEE 802.11 specifications [1], when a data or an ACK frame is lost over a WLAN, the sender (e.g., an MN) retransmits the same data frame to the receiver (e.g., an AP) until the number of frame retransmissions reaches a predetermined retry limit. If RTS (Request To Send)/CTS (Clear To Send) is applied, the retry limit is set to four; otherwise, it is seven. (These values actually depend on each vendor.) Therefore, a data frame can be retransmitted a maximum of four or seven times (the initial transmission and three/six retransmissions), if necessary. If the MN does not receive an ACK frame within the retry limit, it treats the data frame as a lost packet. In addition, RTT increases due to retransmissions over a WLAN. Therefore, we can see that a data frame inherently experiences retransmissions over a WLAN before the occurrence of packet loss or the increase of RTT, irrespective of the RTS/CTS.

3.2 Advantages

Use of the number of frame retransmissions has the following three advantages: (i) MN movement detection, (ii) radio interference detection, and (iii) ease of setting of the threshold triggering the handover processes. First, when the MN moves during communication, the wireless link condition is degraded due to the distance from the AP and any interfering objects located between the MN and the AP. As described in Section 3.1, a data frame will experience retransmissions due to the degradation of the wireless link condition before the occurrence of packet loss or the increase of RTT. Thus, if the number of frame retransmissions is used as a handover decision criterion, the MN can detect the degradation of wireless link condition with its own movement before the communication quality is actually degraded.

Next, in radio interference environments, the number of frame retransmissions has another advantage that the signal strength criterion can never imitate. For instance, with signal strength, the MN cannot detect the communication quality due to the radio interference either, because signal strength is not influenced by radio interference at all. However, in radio interference environments, frame retransmissions frequently occur due to collisions between transmitted frames. As a result, the communication quality is degraded. Therefore, using the number of frame retransmissions, the MN can detect degradation of communication quality due to radio interference.

Lastly, ease of determination of the threshold triggering the handover processes should be noted here. As mentioned earlier, signal strength is measured in different ways by each vendor, so that it is necessary to set a different suitable threshold for each WLAN card. The determination of an appropriate threshold, thus, depends upon vendors' implementation of measures. On the other hand, as frame retransmissions can be handled in the same manner in all WLAN cards, we can set the same threshold for every WLAN card, unlike the signal strength. In addition, we can simply set the threshold by plain numbers (e.g., 1, 2, 3,..., n).

3.3 Disadvantages

Although we described the advantages of the number of frame retransmissions in the previous section, it also has its disadvantages. These disadvantages are as follows: (I) an MN cannot detect change in wireless link condition without transmission of data frames, and (II) cross-layer architecture is indispensable to notify the existing mobility management technologies on upper layers of the number of frame retransmissions. First, the number of frame retransmissions cannot be measured until data frames are sent. For instance, the MN cannot estimate the wireless link condition of a new AP by the number of frame retransmissions before associating with the new AP. In this case, another criterion, e.g., signal strength, is necessary to estimate the wireless link condition. Therefore, an MN cannot detect wireless link quality without transmission of data frames. Next, to introduce this heuristic into the existing mobility management technologies, as the information held in each layer cannot be accessed from different layers due to the concept of the traditional layered architecture, a cross-layer architecture is necessary for achieving accessibility from different layers.

4. Conclusion

In this paper, we have discussed handover decision criteria to maintain communication quality during handover. In particular, we mentioned that the degradation of communication quality at handover initiation becomes a critical issue. To seamlessly move across multiple WLANs divided into different IP subnets, an MN should execute the handover process while reliably and promptly detecting degradation of the wireless link condition before deterioration of communication quality actually occurs. Next, we argued that a handover decision criterion should satisfy the following two requirements: (1) MN movement detection, and (2) radio interference detection. To satisfy these two requirements, we proposed the number of frame retransmissions as a simple heuristic for the handover decision. Although this heuristic has some disadvantages, we consider that the number of frame retransmissions is an important heuristic to maintain communication quality during WLAN handover.

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