論文内容の要旨

論文題目

Improving Handoff Performance in IEEE 802.11 Wireless Networks
(IEEE 802.11 無線ネットワークにおける高速ハンドオフ機構に関する研究)

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This dissertation describes the design and development of systems to improve handoff performance in IEEE 802.11 wireless networks. Handoff is the process through which a client switches the associated access point. To achieve handoff faster means to provide not only higher throughput to best-effort applications, but also uninterrupted service to delay-sensitive applications on the move. The original IEEE 802.11 standard does not support it, because it was designed to provide wireless connectivity for fixed, portable, and moving clients mainly *within* a basic service set.

Link-layer handoff is composed of four sequential phases: detection, channel scanning, link-layer authentication and reassociation. The standard handoff incurs latency in the magnitude of hundreds of milliseconds to several seconds, and the channel scanning latency accounts for more than 90 % of that. The necessity of channel scanning phase comes from a client's *inability* to acquire information about nearby APs on different channels while communicating with the currently associated AP. Its large latency lies on the *inefficiency* that the standard mandates a client not only to scan through all the channels regardless of AP's existence on it, but also to wait for a fixed amount of time at each channel just in case more responses might arrive.

We propose two fast handoff methods to address these *inability* and *inefficiency*, respectively. As for handling *inability*, we aim to completely eliminate channel scanning phase by enabling clients to obtain information about the APs available in range while exchanging

data frames with a currently associated AP. We further require that 1) nearby AP information should be promptly updated in a dynamically changing radio environment, and 2) the ease of deployment, which is the biggest strength of IEEE 802.11 wireless networks, should be kept. As for handling *inefficiency*, we aim to improve channel scanning phase by proposing a novel usage of the open system authentication phase, which became redundant with the advent of WPA. We further require that 1) no modification should be made to the current standard, 2) the handoff metrics (e.g. signal strength, traffic load, etc) should be promptly acquired *during* the handoff procedure, and 3) the fast handoff scheme should work with only software upgrade on the client side.

To achieve the first improvement, we have developed a fast handoff scheme, called OkScan, that integrates a shared beacon channel into IEEE 802.11 wireless networks for completely eliminating channel scanning latency. The basic idea behind OkScan is to offload management information to a second interface over a dedicated frequency band. We adopt the hardly used channel 14 as a dedicated extra channel to advertise the AP's existence, where clients can update information about geographically nearby APs by listening to it. Our proposed method enables clients to keep track of nearby APs operating on any PHY types and any channels. In this dissertation, we show the theoretical analysis on nearby AP information update rate in comparison to related work, and the effectiveness of our system through implementation and experiments.

To achieve the second improvement, we have developed a fast handoff scheme, called AuthScan, that provides a novel usage of the open system authentication phase for reducing channel scanning latency. The basic idea behind AuthScan is to exploit multiple *Authentication Request / Response*. AuthScan maintains a target AP list cached from a client's previous handoffs, and performs unicast scanning by transmitting not *Probe Request* frames, but *Authentication Request* frames only to the selected APs. The next AP is selected by comparing quickly acquired handoff metrics during the handoff procedure. In this dissertation, we show the theoretical handoff latency in comparison to related work, and the effectiveness of our system through implementation and experiments.

In addition, as a real case application, we extend AuthScan to increase the connected time to Wi-Fi HotSpots while moving around in Tokyo by subway. In Tokyo, approximately 97 % of subway stations are densely covered by three different service providers, but effectively utilizing network connection on the move requires a greater degree of management due to the different range of user mobility. We aim to mitigate Wi-Fi connection interruption issues arising in this environment. We investigate the commercial 802.11 HOTSPOT network deployed in Tokyo Metro to understand the target environment and, therefore, to clarify the obstacles to our goal and list up the environmental requirements. Two obstacles to our goal are: 1) a slow handoff process across overlapping coverage areas at stations, and 2) a slow connection re-establishment at the end of non-coverage area in the tunnels. Three environmental requirements are 1) client software upgrade only, derived from no right to modify the commercially deployed APs, 2) fresh handoff metrics acquisition, derived from train speed high mobility, and 3) excessive management traffic generation avoidance, derived from a power-drain concern for battery-operated mobile devices.

We have developed a system to provide a fast handoff, by an extension of AuthScan, and fast non-coverage area recognition. The basic idea behind fast non-coverage area recognition is to take advantage of the key attributes of the target environment: 1) centrally managed limited number of APs, 2) strong mobility pattern. While the behavior experienced when no preferred AP is found during scanning phase is implementation specific, our system performs passive scan only on the target channel which can be obtained from previously available nearby AP topology. When a beacon frame arrives, a client executes AuthScan handoff process by comparing quickly acquired handoff metrics during the unicast channel scanning procedure. In this dissertation, we analyze the theoretical performance improvement of non-coverage area recognition, and show the effectiveness of our system through implementation and field experiments in a real subway environment.

In summary, this dissertation describes two fast handoff methods to address *inability* and *inefficiency* of the standard channel scanning phase in the IEEE 802.11 wireless networks. We also describe a real case application of AuthScan to increase the connected time to Wi-Fi HotSpots while moving around in Tokyo by subway. All the proposed methods are implemented and their performances are investigated through field experiments.