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A FUZZY LOGIC BASED HANDOFF APPLICATION ON OPEN-SOURCE PLATFORM

ABSTRACT

Handoff, in wireless networks, occurs when a mobile terminal switches from one network to another. Selection of the optimum access point is a challenge that impacts the overall network stability, quality of service provisioning, resource utilization, and user satisfaction. Nowadays, there are many mobile platforms for mobile terminals. Android, Google's open-source framework, consists of an operating system and software stack for developing applications on mobile devices. The Android framework provides capabilities of the Linux kernel and its SDK provides the tools and APIs for developing applications on the Android platform using the Java programming language. In this study, we have developed an Android application with a user friendly graphical interface, which switches the connection between IEEE 802.11b and 802.11g Wi-Fi hotspots using its fuzzy logic based handoff decision making module. The results show that desired performance results could be obtained with the software developed.

Keywords: Handoff, Android Operating System, Fuzzy Logic, WLAN

AÇIK KAYNAK PLATFORMU ÜZERİNDE BULANIK MANTIK TABANLI EL DEĞİŞTİRME UYGULAMASI

ÖZET

Kablosuz ağlarda el değiştirme işlemi, hareketli bir terminalin bir ağdan diğer bir ağa geçişinde gerçekleşmektedir. En uygun erişim noktasının seçimi, genel ağ kararlılığını, hizmet sağlama kalitesini, kaynak kullanımını ve kullanıcı memnuniyetini etkileyen bir problemdir. Günümüzde, hareketli terminaller için birçok çalışma platformu bulunmaktadır. Google'ın açık kaynak yapısı olan Android, hareketli terminallerde uygulamalar geliştirmek için işletim sistemi ve yazılım kümesinden oluşmaktadır. Android sistemi, uygulamalar geliştirmek için Java programlama dilini kullanan SDK araçları ve Linux çekirdeğinin yeteneklerini sağlamaktadır. Bu çalışmada, IEEE 802.11b ve IEEE 802.11g Wi-Fi erişim noktaları arasında, bulanık mantık tabanlı el değiştirmeye karar verme birimini kullanarak bağlantı aktarımını sağlayan, kullanımı kolay grafik ara yüzüne sahip bir Android uygulaması geliştirilmiştir. Telefon ekranında görülen sonuçlar, istenilen başarımların geliştirilen uygulama ile sağlandığını göstermektedir.

Anahtar Kelimeler: El Değiştirme, Android İşletim Sistemi, Bulanık Mantık, WLAN

1. INTRODUCTION (GİRİŞ)

Currently, there are different wireless network technologies deployed around the world. Examples include cellular networks (e.g., GSM/GPRS, UMTS), metropolitan area networks (e.g., IEEE 802.16, WiMAX), wireless local area networks WLANs (e.g., IEEE 802.11a/b/g), and personal area networks (e.g., Bluetooth). Wireless network technologies are different from each other usually in terms of bandwidths, frequencies, latencies, and etc. Indeed, no single technology simultaneously provides a low latency, high bandwidth, and cost-effective services to all mobile users. So as to enable seamless communications in wireless environment, providing support for well-organized handoff between the various technologies will play a crucial role [1]. Therefore, the next generation network concept supports at cooperation of these different wireless technologies in order to provide QoS supported and cost efficient connections at anywhere and anytime. Although mobile users expect to get both real-time services (voice transfer, video conferencing etc.) and non-real time services (video transfer, simple message service etc.) with minimum cost and optimum quality, a single wireless access point cannot satisfy the requirements of all current and upcoming services. Hence, the coexistence of heterogeneous wireless networks to carry out application requirements and user expectations is very important issue. The next generation wireless networks should be integrated to form a heterogeneous network which ensures user mobility and service continuity by seamless switching between different technologies at anywhere and anytime. In order to provide seamless mobility between various wireless technologies overlapped, handoff algorithms need to be developed for next generation wireless structures. Handoff is described as a process of transferring an ongoing call or data session from one access point to another in wireless networks. Traditionally, handoff process has been considered among wireless networks using the same access technology (e.g., GSM to GSM). This type of handoff process is defined as horizontal handoff. The other type of handoff named vertical handoff is developed for switching between different wireless technologies (e.g., GSM to Wi-Fi). Nowadays, with the emerging of overlapped various wireless networks, the handoff is a more problematical process.

IEEE 802.11 is a set of standards performing wireless local area network computer communication in the 2.4 - 5 GHz frequency bands. The 802.11 products include over the air modulation techniques. The most widely used are those defined by the 802.11b and 802.11g protocols, which use the 2.4 GHz ISM band. 802.11b and 802.11g use the direct sequence spread spectrum signaling (DSSS) and orthogonal frequency division multiplexing (OFDM) methods, respectively. Wireless network technologies are mostly utilized both of portable computers (i.e. laptops) and mobile terminals (i.e. mobile phones). Mobile terminals, especially mobile smart phones appeal to users by reason of their small dimensions. Nowadays, they also have operating systems like laptops and desktops computers. These new environments will show the way to new applications and will enable greater integration with existing online services. Android is a widely accepted open source operating system for mobile devices that provides an operating system, an application middleware layer, a Java software development kit (SDK), and a group of system applications. As a result of that, specific classes of Android operating system provide the primary API for managing all aspects of Wi-Fi connectivity and management.

In this study, we have developed an application for Android mobile phones that has a user friendly interface for controlling and monitoring Wi-Fi hotspot connections. In this application, we have utilized a handoff decision making algorithm [2] based on fuzzy logic.

For the application developed, we have used two Wi-Fi hotspots with IEEE 802.11 b and IEEE 802.11 g protocols, and a smart mobile phone with Android operating system. The contributions of this study can be summarized as follows: (i) to the best knowledge of authors, developed application employs handoff decision based on fuzzy logic using Android mobile phone is the first, (ii) in addition to that, it has a user friendly interface for managing and controlling Wi-Fi access points.

2. RESEARCH SIGNIFICANCE (ÇALIŞMANIN ÖNEMİ)

Although the handoff concept is relatively new, several studies can still be found, here, we have searched the handoff issue only based on sophisticated (i.e. fuzzy logic) algorithms with hardware implementation in 802.11 wireless networks in the literature. In [3], the authors proposed a fast handoff scheme called AuthScan for IEEE 802.11 Wireless Networks. They implemented a prototype of AuthScan client on an IBM Thinkpad X31 (CPU Pentium M 1.7GHz, 1GB RAM) with an Atheros AR5212-based wireless interface. It runs Debian Linux 4.0 Etch with a 2.6.18-5 kernel.

Full scan handoff, smooth handoff and greedy smooth handoff by software was implemented in [4]. The full scan handoff is used to emulate the handoff controlled by the wireless card firmware. The station is equipped with an 802.11b PCMCIA card using the Intersil Prism2 chipsets. The HostAP driver is used to drive the wireless card. The implementation is based on the Linux Wireless Tools. It monitors the current AP's signal quality and starts the discovery phase when the current AP's RSSI is low. In [5], they proposed a Fuzzy Logic handoff scheme to enhance the current scheme to improve the handoff latency under the IEEE 802.11 wireless network. RSS information was only used for handoff initialization in these researches and generally on laptops. The differences of our study can be summarized as; (i) the developed application employs handoff decision based on fuzzy logic using Android mobile phone, (ii) data rate and monetary cost parameters are taken into account for making handoff in addition to RSS information, (iii) OPNET and MATLAB software tools have been cooperated for getting more realistic performance results and fuzzy rules [2], which make hardware implementation easy.

In this study, we developed a fuzzy logic based handoff algorithm which considers the parameters; data rate, monetary cost, and RSSI as inputs in order to handle any handoff process. We implemented the algorithm which also leads for vertical handoff, on Android mobile phone.

3. ANDROID APPLICATION DEVELOPMENT (ANDROID UYGULAMA GELİŞTİRME)

The Android operating system is based on the Linux kernel that provides low-level services to the rest of the system. Besides, Android is a distribution of Linux that includes a Java Virtual Machine, with Java being the preferred programming language for most Android applications. Android application runs in its own process, with its own instance of the Dalvik virtual machine (VM) developed by Google. The Dalvik VM executes files in the Dalvik Executable (.dex) format which is optimized for Android phones. Dalvik VM relies on the Linux kernel for underlying functionalities such as threading and low-level memory management [6]. The Android SDK ensures libraries needed to interface with the hardware and develop an Android application [7]. There are four building blocks in an Android application model: Activities, Services, Broadcast Receivers, and Content Providers that offer abstractions to support developers to build user interfaces, control platform or application events, build background services and reach all kind of data in a clear way. Android provides access to a

wide collection of useful libraries and tools that can be used to build popular and useful applications. In addition, Android contains a full set of tools that provide high productivity and deep insight into applications. Today, there are already many mobile platforms on the market, including iPhone, Java Mobile Edition, Symbian, Windows Mobile, BlackBerry, etc. The terms of free development platform based on Linux and open source, component-based architecture, and portability across a wide range of current and future hardware etc. are provided efficiently by Android on mobile phones.

4. FUZZY LOGIC BASED HANDOFF DECISION ALGORITM (BULANIK MANTIK TABANLI EL DEĞİŞTİRME ALGORİTMASI)

Advanced handoff decision algorithms should consider more than one handoff decision criteria and an algorithm to combine and process these criteria. Artificial intelligence based systems such as Fuzzy Logic and Artificial Neural Networks are good candidates for pattern classifiers due to their nonlinearity and generalization capability [8]. Applications of fuzzy logic are found in many research and application fields, including artificial intelligence, engineering, computer science, pattern recognition, and etc. A fuzzy logic system is formed a set of IF-THEN linguistic rules given by the expert which is regarded as knowledge base. In general, handoff includes three steps; handoff initiation, handoff decision, and finally handoff execution. Firstly, handoff initiation contains some preparation for a handoff process such as the measurement of RSS, SNR, battery level, mobile speed, and etc. In the second step, handoff decision algorithm controls the current network connection, decides whether a handoff is necessary or not, and chooses the appropriate access point to handoff. Finally, handoff execution establishes the connection with the new access point. Before hardware implementation, for more realistic performance results, we performed a simulation model using OPNET Modeler and MATLAB [2, 9]. Fuzzy logic algorithm module is modeled using MATLAB and the network side of the scenario was implemented in OPNET Modeler simulation software. During the simulation, we used both programs worked together for more sensible estimation and substantiation. Then, for developed Android application, the simulation results are taken into account and used in the handoff application. During the handoff initiation process, we consider three widely used parameters; received signal strength (RSS), data rate (DR) and monetary cost (C). Membership functions of data rate, RSSI, and monetary cost are given in Ref [2, 9] with detailed information about fuzzy logic system. According to the available APs' parameters (RSS, DR, C), the fuzzy inference system produces an output (APCV, Access Point Candidacy Value) which describes the candidacy level of APs and varies from 0 to 10. For example; if an Access Point is able to support a data rate of 50 Kbps, has a cost of 0.1 unit and RSS of -63 dBm then the APCV of this hot spot is calculated as 9.2484 as can be seen in table 1.

Table 1. 25 Kbps data transfer fuzzy rule examples
(Tablo 1. 25 Kbps veri iletimi bulanık kural örnekleri)

if (datarate = 50 AND cost = 0.1 AND rss.level < -30 AND rss.level > -76) : APCV = 9.2484
if (datarate = 50 AND cost = 0.1 AND rss.level = -76) : APCV = 8.6464
if (datarate = 50 AND cost = 0.1 AND rss.level = -77) : APCV = 8.0
if (datarate = 100 AND cost = 1.0 AND rss.level < = -80) : APCV = 0.3625
if (datarate = 100 AND cost = 1.0 AND rss.level==-79) : APCV = 5.2378

Table 2. 100 Kbps data transfer fuzzy rule examples
(Tablo 2. 100 Kbps veri iletimi bulanık kural örnekleri)

if (datarate = 50 AND cost = 0.1 AND rss.level < -30 AND rss.level > - 76) : APCV= 1.0
if (datarate = 100 AND cost = 1.0 AND rss.level < -30 AND rss.level > -76) : APCV= 2.5
if (datarate = 100 AND cost = 1.0 AND rss.level = -76) : APCV= 2.5
if (datarate = 100 AND cost = 1.0 AND rss.level = -78) : APCV= 2.5
if (datarate = 100 AND cost = 1.0 AND rss.level <= -80) : APCV= 0.3625

The obtained APCV values are used in the developed Android application for handoff implementation. In the simulation model and hardware implementation, two Wi-Fi access points are used that served with 802.11 b and 802.11 g protocols. We assume each of access point have unique monetary cost, 0.1 unit and 1.0 unit, respectively. And the throughput values of access point for one user are 50 and 100 Kbps. Table 1 and 2 show some of 25 Kbps and 100 Kbps data transfer fuzzy rules which are embedded to Android application.

5. THE ANDROID APPLICATION DEVELOPED (GELİŞTİRİLEN ANDROID UYGULAMASI)

An Android application consists of a set of activities. An activity is a user interaction that may have one or more input screens. In our Android application, there are three activities named Wi-Fi Control, Wi-Fi RSS Indicator and fuzzy logic based Wi-Fi Selector that employs handoff process, respectively. Our application has graphical interface with three tabs each has its own activity. An Android mobile phone and two Wi-Fi access points are shown in Figure 1.

Figure 1. Android phone with the application and Wi-Fi APs
(Şekil 1. Android telefon, Wi-Fi erişim noktaları ve uygulama)

In the first tab, available Wi-Fi APs are controlled and managed easily. The user can enable or disable Wi-Fi function of phone and select one of Wi-Fi APs listed to connect. Wi-Fi APs are arranged in order of RSS as shown in Figure 1. Using the second tab, users can observe RSS information of APs found with a graphical presentation. In this activity, mobile phone scans the environment for every second and the graphic is updated periodically. This activity is shown in Figure 2.

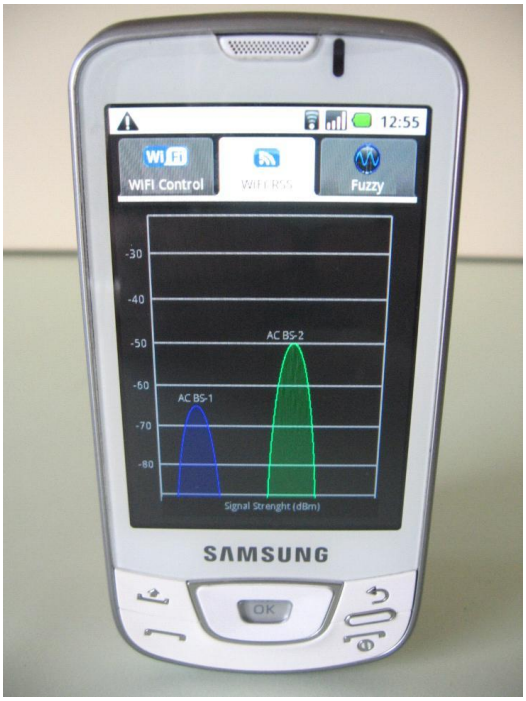

Figure 2. Wi-Fi RSS graphic interface
(Şekil 2. Wi-Fi RSS grafik ara yüzü)

With the last tab, the fuzzy logic based handoff decision algorithm is introduced. Wi-Fi APs are shown with calculated APCV values in this activity. As we mentioned before, APCV describes the candidate values of APs for deciding handoff initialization and choosing the best candidate AP. In our simulation model, we implemented two different data transfer application scenarios with 25 Kbps and 100 Kbps. Each of the Wi-Fi APs assumed to have its own data rate support, and monetary cost values. The first AP that serves with 802.11 b standard has 50 Kbps data rate support, and 0.1 unit cost. On the other hand, second AP has 802.11 g standard with 100 Kbps data rate support, and 1.0 unit cost.

For demonstration, we used two options with radio buttons which imply data transfer applications, 25 Kbps and 100 Kbps, respectively. According to selected application, APCV values of APs are obtained and shown on screen. APCV of each available AP is compared with that of current AP. If the difference between the compared values is equal to or greater than the HR (i.e., 2) then the handoff process initialized and the new AP is chosen as a serving node. In Figure 3, the handoff activity is illustrated.

Results of the scanning access point contain enough information (i.e. frequency, RSS level, SSID, BSSID, capabilities) to make decisions about what access point to connect to [6]. In addition to those classes, several classes and their methods are available in the Android libraries.

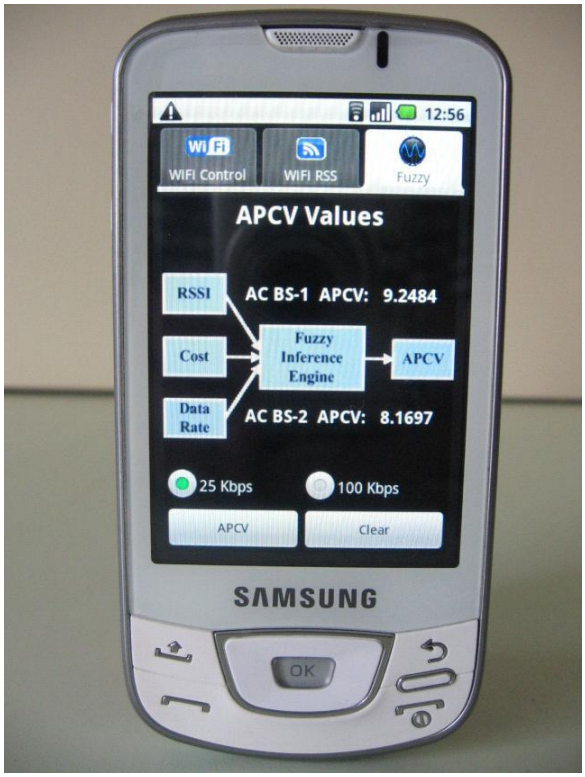

Figure 3. Wi-Fi fuzzy logic based handoff interface
(Şekil 3. Wi-Fi bulanık mantık tabanlı el değiştirme ara yüzü)

6. CONCLUSIONS (SONUÇLAR)

This paper introduces a fuzzy logic based handoff decision application with a user friendly graphical interface for managing the Wi-Fi APs on Android mobile phone. In general, handoff methods must consider many parameters including user profiles, application requirements, and network conditions. In this work, a fuzzy-based handoff decision system which combines data rate, RSSI, and monetary cost parameters is utilized in order to satisfy both user and network requirements for next generation wireless heterogeneous networks. The visual results show that the developed fuzzy logic based handoff decision algorithm is able to determine the most appropriate access point under different dynamic working conditions. To the best knowledge of the authors, this study which presents a handoff application for Android platform in order to select appropriate Wi-Fi access point is the first in the literature.

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