

An Android System Design and Implementation for Telematics Services

Yong-Hua Cheng, Wen-Kuang Kuo, Szu-Lin Su
Institute of Computer and Communication Engineering
Department of Electrical Engineering

National Cheng Kung University, Tainan, Taiwan
e-mail: cyh@itri.org.tw, wkuo@ee.ncku.edu.tw, ssl@ee.ncku.edu.tw

Abstract—The Telematics is the integration of telecommunication and informatics, also known as ICT (Information and Communications Technology). The application trend of Telematics is to establish a user friendly vehicle communication environment to merge the information for the traffic safety, road navigation, remote business, A/V entertainment, etc. The key technologies of Telematics are the heterogeneous communication and information fusion. This paper aims to design a Android-based mobile device platform that integrated with network management functions and MOST (Media Oriented Systems Transport) technologies to utilize multiple network access and Telematics services. The platform composed a heterogeneous network management algorithm which includes roaming and sharing functions to maintain the qualities of services and satisfy different kinds of scenario needs. Besides, we implemented those technologies based on Android software stack with X86 based real targets, such as Car PC or mobile internet device (MID). The heterogeneous network management and Telematics service functions are implemented as the user defined libraries with Android software stack from kernel to application layers to offer better qualities of user services for different kinds of environments. The multimedia streaming and telecommunication sharing scenarios can be also realized by integrating the MOST networks with the Android system to provide more real-time information and entertainment services with quality guarantee. The proposed Android system could be used in home, mobile and vehicular environments to realize ubiquitous social sharing networks and provides the seamless communication efficiency.

Keywords —*Telematics, Heterogeneous network, Android.*

I. INTRODUCTION

The rapid progress of wireless communication in recent years extends the information and communication services from digital homes to mobility life. Different types of wireless communication technologies are widely applied to our daily life so that the demands for accessing internet resources through wireless devices also increase rapidly.

The current wireless communication technologies follow three major trends. First, the mobile communication technologies are expanded from providing pure voice services, such as GSM, to IP-based network services, such as GPRS and HSDPA which includes services of voice, high speed data and multimedia streaming. Second, the broadband network technologies are expanded from providing local Internet access, such as ADSL and WiFi, to widely area and high speed mobility Internet access, such as DSRC, WiMAX. Third, the integration of information and communications that integrates different types of wireless communication technologies to

provide IT-enabled services and applications. The information and communication technologies (ICT) extend the developments of all types of handheld mobile devices to offer real time streaming services in heterogeneous network environments.

Besides, the Internet Protocol (IP), being the common convergence layer for heterogeneous networking, opens new business opportunities enabling mobile terminals equipped with several wireless/wired access technologies to maintain the Internet connectivity. In such potentially scenarios, the terminal might have the capability to gather information of the surrounding access networks to make the accurate network selection and optimized handover decision.

Supporting seamless roaming between heterogeneous networks such as 802.11, WiMAX, and HSDPA requires several functionalities to be taken into account such as network discovery, network selection, and service continuity. In order to achieve ubiquitous roaming in short, medium and long range heterogeneous networks, one of the important issues is to enhance seamless handover for heterogeneous networks effectively and rapidly. The proposed heterogeneous network management algorithm integrates the channel estimation information to estimate the change of adaptive signal-tracking decay, and also improves the estimation handover correctness and reduces the system computation load.

Moreover, interactive applications such as VoIP and streaming media have stringent performance requirements on end-to-end delay and packet loss. To maintain the service connections and support the qualities of services (QoS) for different applications according to the network status are an important issue. The proposed heterogeneous network management algorithm not only manages the heterogeneous networks handover, but also provides efficient resource sharing in the heterogeneous network environment. We also design the seamless handover functionality in the proposed algorithm to support the ubiquitous computing.

We implement the proposed heterogeneous network management algorithm on the Android-based mobile device platform. Android is a software stack for mobile devices that includes an operating system, hardware drivers, middleware and key applications. It allows developers to write managed code in the Java language, controlling the mobile device via Java libraries. The proposed Android-based mobile device platform integrating with heterogeneous network technologies can be applied for many scenarios in our life to realize ubiquitous services sharing and roaming for various network environments.

II. SYSTEM ARCHITECTURE

The developed system integrates technologies of heterogeneous networks management and Android software system design. The system can serve as a Home Entertainment Gateway, a Vehicle On-Board Unit (OBU), or a portable network device. People can access the wired/wireless Internets more conveniently and effectively via the system. One of the application scenarios of Android system is shown in Fig. 1.

The developed system equipped with heterogeneous network interfaces can provide with two functions: Roaming and Sharing. The Roaming function indicates that the system can search and choose the wireless network with best resources (ex: RSS, Bandwidth) for users according to the surrounding environment. This is especially helpful when the system is used for roaming between the homogeneous or heterogeneous networks. The Sharing function indicates that the system can allocate the available resources to all users when the system is connected with multiple wired/wireless networks.

For example, when people stay at home or in the building, the system can be started up with the Sharing function and acted as a Home Entertainment Gateway. The system can dynamically allocate wired and wireless network bandwidth for all users connected to the system. When people are outside the building, the system can use the Roaming function and act as an intelligent MID (Mobile Internet Device). The system can choose one or more wireless networks with available resources to satisfy user traffic demand. If people carry the system into a car or a bus, the system will also become a Vehicle On-Board Unit and share the mobile network resources for users on the Vehicle with the Sharing function.

The developed system can communicate with the Home Entertainment Gateway or the Vehicle OBU as a client, and share its network resources for other users as a server. The heterogeneous networks management technology is very important to be implemented for analyzing the multiple network/user conditions, and deciding the resource allocation policy. The communication link of network and physical layer are adjusted adaptively based on the handover decision. The technology also considers the seamless roaming issues to provide better QoS (quality of service) for users.

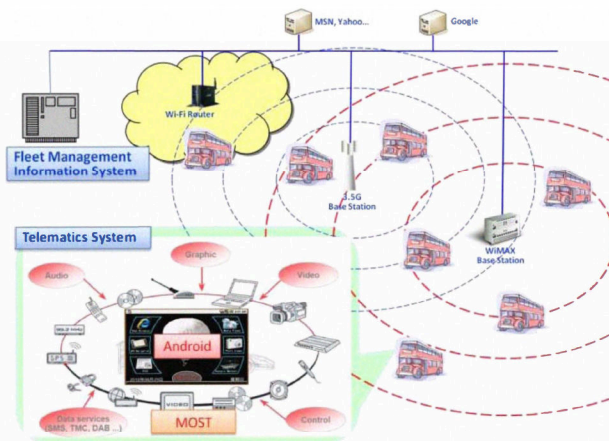


Figure 1. The situational application of Android system

III. ALGORITHM DESIGN

A. Methodology

We proposed a heterogeneous network management algorithm to maintain the qualities of access networks and services. The proposed algorithm shown in Fig. 2 cooperates with Roaming function and Sharing function according to the situational application.

When the system starts up, the system will detect the available network resources and the status of environment. The system decides to use Roaming or Sharing function according to this information or by user commands. The algorithm of the heterogeneous network management can be divided into three processes, and the details of each process are described as follows:

1. Handover Control Process

The middle part of the flowchart shows the process of handover control which includes four steps from physical layer to application layer to guarantee the QoS.

The first step of this process is handover initialization step. The Network Analyzer function monitors the status of networks and predicts the power gain or SINR (Signal to Interference and Noise Ratio) variation of each network. When the system discovers the signal qualities of networks occurring significant variation, the Network Analyzer function notifies the Roaming Function and Sharing Function Processes for the handover initialization.

At the second step of this process, the On-line Service Analyzer function receives the information of available network resources sent from Search New Link module of the Roaming Function Process and examines the characteristics of user services sent from the user/service management module of the Sharing Function Process. Then it decides whether to execute vertical or horizontal handover and reallocates resources to on-line services based on their priorities. In our system, services are divided into different priority classes (i.e. voice is the highest priority, video is the medium priority, and non-real-time traffic is the lowest priority). Due to the limited space, the detail of the resource allocation and handover-type decision algorithms are not presented in this paper.

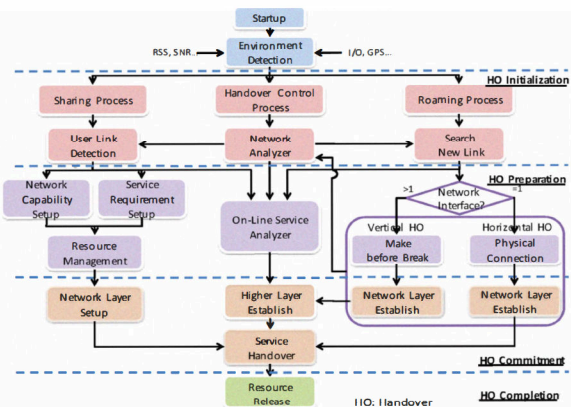


Figure 2. The flowchart of heterogeneous network management

At the third step of this process, if the handover type of a service is vertical handover, the Higher Layer Establish function will setup a new service thread for this service. The new service thread uses the primitives which are established by the vertical handover and Network Link Establish modules to communicate with the new network attachment point (NAP) and continues the old service process. The new service thread will connect to the other communication party via the primitives which establishes new network layer and link layer connections using Heterogeneous NIC. After the new service thread is established, the old service thread connected to the original network attachment point breaks. This is intended to provide seamless services.

The Service Handover function will change the connection of service according to handover type. If the handover type of a service is vertical handover, the application layer service will use the new service thread to continue its service. If the handover type of a service is horizontal handover, the service will not need to setup the new service threads to carry out the service handover processes. The services will be changed the connection to the new access point or base station at the same NIC. The Service Handover function also decides the network layer handover of services relying on the Sharing Function Process.

At the finally step, the system will release the old service process and the old network resource to complete the handover control process. The services will be continued by applying the handover control process at upper layer even if the physical communication link is changed when roaming between the heterogeneous networks. The details of the Network Analyzer function will be described in another paper.

2. Roaming Function Process

The right half part of the flowchart shows the process of the Roaming Function which manages the physical layer handover of the system. The Roaming Function is responsible for choosing the most appropriate network interface according to the surrounding environment.

When the Roaming Function is enabled, the system analyzes the qualities of used networks. The Search New Link function checks the network information sent from the Network Analyzer function to see if necessary to search the new network link for the handover preparation or not. When the quality of used network is going down, the system will search new candidates with better link performances.

If there exists another NIC which uses different wireless technology and has better quality (ex: RSSI, SINR, QoS etc.), the system could execute the vertical handover to make a new wireless physical link before the old physical link break. Next, the Network Layer Establish function will reserve the old IP and routing table information to keep the connections of used services continuously on original communication links, until new IP and routing table of new communication link has been

setup. And then applies the Higher Layer Establish function of Handover Control Process to execute the seamless service handover at Application Framework Layer.

If there is only single wireless network interface, the system will execute the horizontal handover to make the network interface connecting to the NAP with better signal strength or bandwidth according to the information sent from Search New Link function. Next, the Network Layer Establish function will change the IP and routing table information according to the new NAP for the change of communication links, and then applies the Services Handover function of Handover Control Process to execute the service handover at Application Layer.

The handover functions will send the selected NICs' information including RSSI, SINR, and QoS parameters to the Network Analyzer function of Handover Control Process for analyzing the qualities of used networks and services handover constraints.

3. Sharing Function Process

The left half part of the flowchart shows the process of the Sharing Function which uses Resource Management function to control the network layer handover of the system. The Sharing Function is used to allocate the available network resources for users.

When the Sharing Function is enabled, the system analyzes the qualities of used networks. The User Link Detection function detects the user connections and the active NIC statuses sent from Network Analyzer function to see if any network resource varied.

If there exists any NIC being removed from the system or added to it, the Network Capability Setup function (NCS) will analyzes the QoS parameters sent from the User Link Detection function, and classifies the connected networks into several groups of different qualities.

If there exist any user joining to the sharing network or leaving from it, the Service Requirement Setup (SRS) function will update the users' information which includes user preference and the characteristics of online services (ex: the bandwidth, service type, delay, packet loss rate, etc.). Then SRS classifies services into several groups of different QoS requirement according to the service characteristics.

As either of NCS and SRS is enabled, the Resource Management function will be triggered to rearrange connections between the NICs and services according to the information provided by NCS function and SRS function. The loading ratio of each service group of each NIC will be derived. Then the service number in each NIC could be decided.

Finally, the Network Layer Setup function setups the network routing tables with user services and NIC configured by Resource Management function. The results of the resource management will be sent to the Service Handover function to execute the Handover Control Process.

IV. SYSTEM IMPLEMENTATION

The proposed heterogeneous network management algorithm can be applied on the mainstream operating systems, such as Windows, Linux, or Android. Our system implementation is designed based on Android software stack. In this section, we will describe how to implement these functions and applications on the target devices.

A. Android Software Development

The Android system can be implemented on any hardware platforms to realize many Telematics applicable scenarios. Fig. 3 is the implementation flowchart that shows the major components and their relationships. We present the details of major components of Fig.3 as the follows.

To build the Android source files, it will need to use Linux or Mac OS. We apply Linux Fedora and gcc 4.3.2 as our Android building environment. Besides, some software packages are also required: Git, Java JDK, Python, and Repo. Since we develop Android OS on X86 target devices, it is necessary to configure Android system to X86 architecture.

The kernel of Android relies on Linux version 2.6 for core system services, such as security, memory management, process management, network stacks, and driver models. In order to run Android OS on the target device, we need to drive the peripheral hardware of the target device. Some drivers have already included in the Android kernel sources, and it just only chooses these functions and compiles them. Otherwise, we should add the drivers that we need in the kernel. Since some drivers are dependent, such as touch screen and power management, 3.5G modules and USB serials, protocol stacks and network functions, it is important to add or modify the correct driver sources to drive the target device validly. Furthermore, some drivers also need their collocating external tools to work well, such as 802.11 Wireless LAN cards need wireless configuration tools, 3.5G USB modems need 3.5G dialer tools, and GPS navigators need relative libraries. After the kernel sources are configured, we compile the kernel files to build the kernel image.

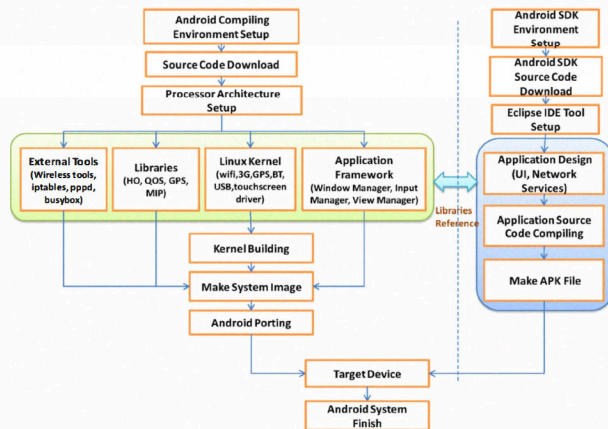


Figure 3. Android system implementation flowchart

The fundamental library is the operating core of Android system, and it takes charge of the surface management, media support, system C library and database engine, etc. The Handover, QoS and GPS functions can be implemented at the user define libraries layer to enhance seamless connections of networks and services, and offer better qualities of network resources and user services.

External tools are indeed required to configure Android system or network functions, and they also link up these functions with the kernel layer and the application layer. So we add some program codes into the Android file system, such as wireless configuration tools, network tools, 3G dialer tools, and Busybox command tools. We also need to modify source codes of some functions of application framework, such as Window Manager, Resource Manager, and so on. The cursor function is also added to application frameworks in our system to make users controlling the Android system more conveniently by remote control.

We design our applications by using Android SDK (Software Development Kit) and Eclipse IDE software tools. Most services need to get the data information from Internet through the wireless devices; therefore the handover management of networks and services is extremely important to enhance the qualities of communication and services. To design applications for Android OS, we must reference relative libraries in the Android file system. The developed applications would be compiled as APK files and then downloaded to the target device that has installed Android OS. Applications could be added or deleted by users arbitrarily at any time.

B. Android System Prototype

In order to realize an Android system with heterogeneous network management, we implemented those technologies which we mentioned in the preceding sections on the X86 based real targets, such as 1 DIN (Deutsche Industrie Normen), Car PC and MID, which are shown as Fig. 4. The network management functions of the system are implemented from physical layer to application layer to satisfy different kinds of scenario needs. The Roaming function is implemented at the physical layer and MAC layer to maintain the link layer handover. And the Sharing function is implemented at the network layer and application layer to maintain the connections between networks and services. These functions are implemented as the user-defined libraries of the Android software stacks to provide the heterogeneous network management functions for the Android system.

And the Android applications we designed including Web browser, GPS Navigation, RSS, Media player, Photo viewer, and Google market. These applications are implemented on the Android system to provide a user-friendly GUI for Telematics services as shown in Fig. 5.

This Android system that integrates with network management functions and MOST (Media Oriented Systems Transport) technologies could be acted as a Telematics system, which is shown as Fig. 6. It will satisfy the mobile communication requirements for passengers by applying 3G or WiMAX network interfaces as Internet access and applying

WiFi or MOST network interfaces for local network sharing. The WiFi network interface can be acted as a wireless access point to provide passengers connecting the portable network device with the Android system. And the MOST networks can be acted as vehicular equipment networks to integrate the master car PC and slave car PC. The MOST networks that owned high speed network technologies can provide adaptive QoS guarantee for real-time multimedia transportation and network communication, and it supports the data transportation rate up to 50/150Mbps. It provides real-time information and entertainment services for passengers travelling by vehicles or buses.

Besides, this Telematics system can also provide fleet management functions by integrating backbone management systems. The fleet management system can be custom designed according to the characteristics of fleets, and it can also provide traffic information, advertising, life information, and location-based services (LBS) by cooperating with different services providers. The above functions of Android system are listed in specification Table I.

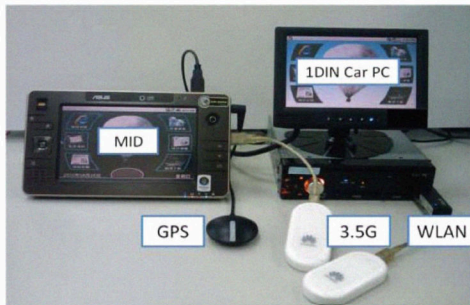


Figure 4. The prototypes of Android system



Figure 5. The developed Android applications

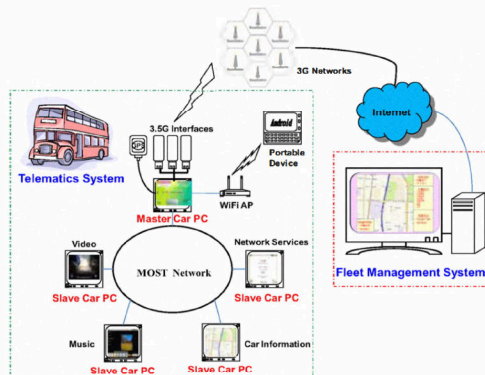


Figure 6. Android system integrated with MOST networks

Table I. The specifications of the Android system

Application	Middleware	Hardware
<ul style="list-style-type: none"> ■ JAVA with Android SDK ✓ Fleet Management ✓ Vehicle Monitoring ✓ Vehicle Diagnosis ✓ Weather Info. ✓ Google Talk ✓ Google Navigation ✓ LBS ✓ RSS ✓ Media Player ✓ Internet Radio ✓ Bandwidth Sharing ✓ Multiple Backup 	<ul style="list-style-type: none"> ■ Android OS ✓ Device Driver • Communication • MOST 50 • Touchscreen/ • Microphone • Audio/Video/Camera • Storage Device ✓ External Tool • 3.5G • WiFi • WiMAX ✓ Library • GPS • Network Management 	<ul style="list-style-type: none"> ■ CPU: ✓ X86 ■ I/O: ✓ MOST 50 ✓ USB Host x N ✓ Touchscreen ✓ Microphone ✓ Audio/Video ■ Multi-USB Devices: ✓ GPS ✓ 3.5G ✓ Wi-Fi ✓ WiMAX ✓ USB Disk

V. CONCLUSIONS AND FUTURE WORKS

In this paper, we proposed an Android-based mobile device platform which provides the heterogeneous network management functionalities to guarantee the communication quality. In order to achieve ubiquitous computing, the proposed algorithm supports seamless handover via effective and rapid resource and handover managements between heterogeneous networks.

In the future, we will design a more sophisticated resource management algorithm to enhance the QoS during the network roaming and sharing processes. The algorithm will provide all resources of heterogeneous network interfaces of the system for multi-users sharing, and achieve an intelligent load-balance state of the system. We will also enhance functionalities of the Android system to provide the Cloud Computing, fleet management and location-based services, etc. Besides, the well integration with vehicular network technologies such as MOST will provide more real-time and practical services for users sharing. And different kinds of Android system platforms will be also implemented to provide customized services.

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