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An AutoPC for Supporting In-Vehicle Navigation and Location-Based Multimedia Services

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Abstract: With the rapid progress in the development of wireless technology, the bandwidth of wireless local area network (WLAN) is getting higher and its outdoor transmission distance is also getting longer. It becomes feasible to build a regional communication infrastructure in local areas, e.g., in the campus of an institute or a university, using WLAN. Thus, the design of new generation on-board PCs aims not only to provide conventional navigation services in rural or urban areas, but also to deploy integrated multimedia services in regional areas such as campuses. In this paper we present our design of in-vehicle navigation and location-based multimedia applications in an 802.11b wireless environment. It supports mobile communication based on IETF mobile IP standards with route optimization, smooth handoff, and fast handoff. Furthermore, in order to encourage fast deployment and to reduce system costs, we utilized open technologies in designing our prototype system. The developed AutoPC is a real-time embedded system platform on a single-board PC with GPS, featured by a downsized embedded Linux and a bilingual windows system. The platform supports applications such as in-vehicle navigation, real-time traffic information, MP3 player, and MPEG-4 streaming through mobile IPv4. This prototype is evaluated on a campus-wide 802.11b network, where two neighboring access points are placed about 150 meters apart from each other along the roadside such that a road in the campus is fully covered by 802.11b radio signals. Our preliminary experiments show that the low handoff overhead makes it possible for an in-vehicle AutoPC to run video streaming application seamlessly on the road even when the car speed is up to 50 km/hr. Besides, a 486-level platform is powerful enough to support in-vehicle navigation and to play MP3 smoothly, but a more powerful CPU is required to run our RTP-based MPEG-4 video streaming applications.

INTRODUCTION

Mobile and wireless communication technologies are ushering in a new era. Not only serving the demand for wireless voice communication, the increasing use of cellular phone has also created a strong demand for mobile data communication. These demands are driving the creation of a new computing world that will encourage the development of new applications especially for mobile and wireless environment.

Different from traditional computing paradigm, location is specific information to mobile computing. Computer applications that utilize location information can provide location-specific services that are more attractive to users. Nowadays the Global Position Systems (GPS) continuously and universally serve as a source of position and location information that are fundamental to mobile computing [5][11]. A GPS-enabled application can then provide more precise and valuable services in response to present place and time.

Integrating with digital maps and geographic information systems, a GPS-based AutoPC equipped in car supporting navigation and route-guidance services has been proved useful to drivers [2][15][21]. Land-vehicle navigation has become one of the most successful applications of GPS [1][8][23]. In addition, an AutoPC will also play an important role in intelligent transportation systems (ITS): it will work as a platform for computation and communication, and become a part of future intelligent vehicle [4][6][9][16]. Although an AutoPC in car demonstrates a mobile platform in nature and it is expected to support more functions, the lack of inexpensive broadband data access restricts its future development [13].

In the wireless communication research areas, recent advancements in wireless local area networks (WLAN) have showed their promises to wireless broadband data access [7]. Following the IEEE 802.11b standard announced in fall 1999, an 802.11b-compliant device can transmit

data up to 11 Mb/s [12]. The newly developed 802.11a standard further enhances the transmission rate up to 54 Mb/s. Since 802.11b access points and network adapters are cost-effective and these products can operate unlicensed in the ISM bands, 802.11b systems have been widely deployed in many in-door buildings and public spaces for wireless Internet access [10].

Furthermore, in an outdoor environment, standard 802.11b equipments can transmit data up to 100 meters away. With an enhanced antenna or increased transmit-power, they can also transmit data more than 200 meters outdoors. These features make 802.11b-based infrastructure feasible to provide inexpensive broadband wireless data access for users within a certain region such as campus or community.

This paper will describe a new navigation environment that has broadband mobile Internet connectivity, and the design of an AutoPC that utilizes this environment to provide in-vehicle navigation and location-based multimedia services.

A CAMPUS GUIDANCE SYSTEM

As the bandwidth of wireless local area network gets higher and its outdoor transmission distance gets longer, there will be more large-scale outdoor WLAN services deployed to serve whole campuses or parks. In addition to conventional navigation services in rural or urban areas, a future GPS-based AutoPC should be able to utilize this broadband access and also navigate a driver within a campus or park.

To comprehend our researches in ITS, we are building an 802.11b WLAN infrastructure as a basis of our campus guidance system. As stated, this infrastructure could provide a cost-effective, high-bandwidth, and autonomous wireless environment, and then we can explore more opportunities for future mobile applications.

Figure 1 shows the proposed architecture of our campus guidance system. Similar to ITS architecture, the guidance system is composed of on-board unit, road-side unit, and center unit. An AutoPC which connects with a GPS receiver and a 802.11b network adapter plays a central role in the on-board unit. It communicates with the outside world through the 802.11b access point and base station in the road side, which is connected to the existing wired backbone. Since this is an all-IP core network, the AutoPC can request location-specific services or contents

from usual Internet servers. Currently we support multimedia, GIS, and real-time information contents in the server unit.

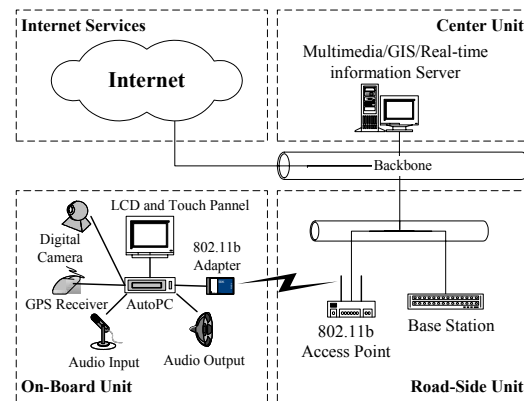


Figure 1. Architecture of a campus guidance system

A MULTI-PURPOSE AUTOPC

For an Internet-enabled AutoPC, there would be more diverse service requests from users. The owner of a large-scale WLAN infrastructure would also like to provide regional specific information to interested users based on location. Besides, the navigation services of a campus guidance system may also interest people who use handheld devices rather than AutoPC. Like the seeking of a portable low-cost platform for in-vehicle navigation [3][14][17][22], there should also be an open interface or platform that supports portability, interoperability and extensibility in the design of a campus guidance system.

System Architecture

The architecture of our multi-purpose AutoPC system is showed in Figure 2. In our design, the Windows framework serves as the middleware between the applications and the underlying operating system and hardware platform. It defines application interface and operating system (OS) abstract interface to maintain portability and interoperability. Applications developed on top of the Windows framework can execute not only on AutoPC, but also on Internet appliances (IA) such as handheld devices and Personal Digital Assistant (PDA). Currently we have developed prototype systems running on single-board PC and Compaq iPAQ PDA under embedded Linux. The version

running under Microsoft Windows CE is also under development.

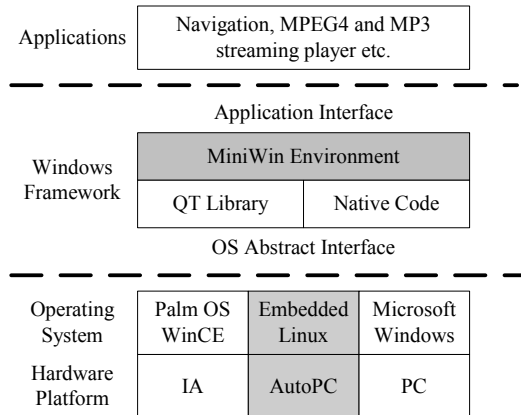


Figure 2. Architecture of a multi-purpose AutoPC system

Embedded Linux

Linux is an open-source OS used and supported by world-wide users. There are also many industrial companies supporting Linux in their products, especially in servers and embedded systems. In order to encourage fast deployment and to reduce system costs, we utilized these open technologies in designing our prototype system.

In our experience, the major efforts to customize Linux for AutoPC include three parts:

1. *Downsizing kernel*: Since Linux is a general purpose OS for personal computers, several functions will not be needed for AutoPC. By reconfiguring and tuning the OS, we can obtain a compact Linux that has small code size and runtime resource requirements.
2. *DOS-like Linux environment*: Linux is a multi-tasking OS that relies on user-level system applications to support secure multi-user environment. In AutoPC, however, it is mainly designed for single user and event-driven environment. So we need to customize Linux as a DOS-like environment and optimize it for single-user runtime environment.
3. *Linux-on-Chip*: For the concern of reliability and hardware cost, there is no hard-disk storage in our AutoPC. The whole system was then stored in ROM or flash memory, and directly boot and executed from ROM.

Windows Framework

Windows framework is the core component of our multi-purpose AutoPC system. It abstracts the complexity of the underlying platform and supports sufficient functions for developers to provide add-on applications. Not only to provide user-friendly environment for users, the windows framework also needs to support convenient development environment for application developers and content providers.

Figure 3 shows the architecture of our windows framework: the bilingual MiniWin environment. As a windows system, it provides a subset of windows functions with compatible Microsoft Windows API that are sufficient for AutoPC applications and mobile services, including full-featured friendly GUI and controls.

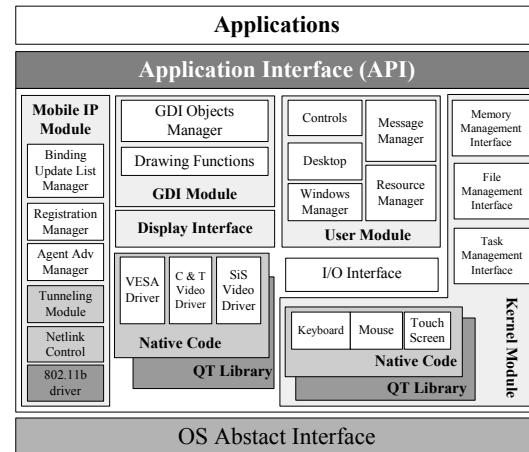


Figure 3. Architecture of the MiniWin environment: a windows framework

In addition to APIs, the MiniWin environment consists of four modules:

1. *Kernel module*: unifying the underlying OS functions and providing primitive system functions to application programs and other modules. It will interact with devices through native code or QT library, a public highly-portable library in Linux, and support memory management, file management, task management, etc.
2. *Graphical device interface (GDI) module*: abstracting the output display device and providing primitive drawing functions to User Module and applications. It may invoke the portable QT library or native calls to support high-performance graph functions that are accelerated by hardware.
3. *User module*: providing classical high-level windows functions through windows

manager, message manager and resource manager.

4. *Mobile IP module*: providing transparent mobile Internet connectivity to applications. To support seamless handoff and packet routing optimization, this module contains binding update list manager, registration manager, agent advertisement manager, tunneling module and network link control module. Although the application is not aware of the existence of this module, it is the major software component to communicate with the base station in order to provide broadband wireless Internet access.

In short, the MiniWin environment is specially adapted to support mobile communication for AutoPC and also applicable to ROM-based and diskless environment.

Mobile IPv4 over 802.11b WLAN

One of the most challenging issues with a campus guidance system is to support broadband Internet access over 802.11b network. At present, mobile IP standards are still under development at IETF; there are not many mobile IP deployment experiences yet [20]. Furthermore, 802.11b network is not designed for mobile IP; the support for mobile node handoff in outdoor environment is insufficient in its original design. An AutoPC working as a mobile node in this severe wireless environment would then need to extend its functions to support broadband data access over WLAN.

Figure 4 shows the overall architecture of our mobile IP design. In the base mobile IP [18], all packets sent from the fixed node are forwarded to the target mobile node via the home agent of the mobile node. In a usual secure network, the packet sent from the mobile node to a fixed node also needs to be tunneled reversely through the visiting foreign agent and home agent. These incur serious performance issue known as the triangular routing problem.

Route optimization technique has been proposed to relieve the routing problem to some extent [19]. However, it relies on the fixed node to directly tunnel packets to the mobile node; besides, the reverse tunneling is still not well addressed in the proposed route optimization.

In our design, a correspondent agent is proposed to support transparent route optimization for fixed nodes and bi-directional route optimization for mobile nodes. Besides, the optimized route can be reused for fixed or

mobile nodes within the same subnet; the binding operations are aggregated to reduce the number of control messages and handoff latency.

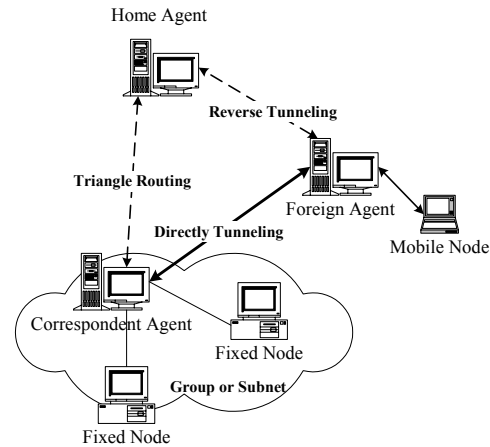


Figure 4. Aggregated bi-directional route optimization for mobile IP

Furthermore, the base mobile IP relies on receiving periodical advertisement messages from the foreign agent to detect handoff passively by the mobile node. The period is usually set to 30 seconds and this incurs long-latency handoff overhead. Adopting the fast-handoff draft standard, we adapted the 802.11b driver to support fast handoff by actively detecting the signal strength. Our preliminary experiment results showed that these improvements can reduce the handoff cost from 15 seconds to below 1 second.

Navigation Applications

To demonstrate our AutoPC under a broadband mobile Internet environment, we have developed prototype navigation applications and location-based multimedia streaming services on top of the MiniWin environment.

Different from conventional navigation systems, many information and data, including maps and real-time information, can be obtained through the mobile Internet link. An intelligent caching mechanism for data and objects will become very important. Furthermore, the department within a campus may like to provide and maintain their own contents and information. The system should develop open interface for content providers and support seamless browsing for users to access various contents from different sources.

In our AutoPC, the in-vehicle navigation system continually obtains location information from the GPS receiver module and real-time information from the mobile network connection. It may also submit a location-based information query or media request to external servers.

As showed in Figure 5, the prototype navigation application incorporates with a map engine module and a viewer module. The map engine manages different data types and map layers, and the viewer module interacts with the user. In addition, the application also supports movement tracking, simulation and replay. The tracked location and route information with time information can be sent back to the center server and used for further route guidance.

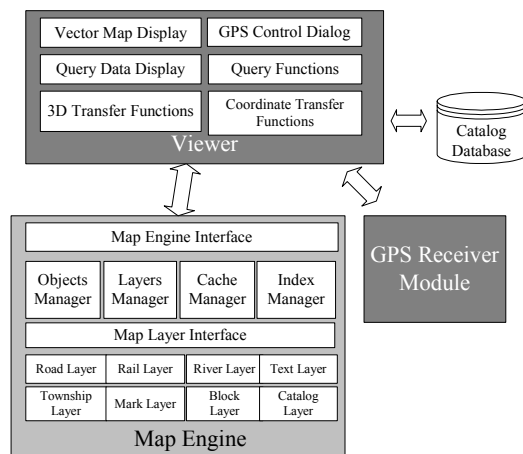


Figure 5. Architecture of the navigation application

Location-based Multimedia Services

A wireless multimedia streaming application running mobile IP can help us examine the feasibility of a campus guidance system over 802.11b network. We have developed streaming players that play MPEG-4 video and MP3 audio songs through the 802.11b link. A stream can be requested based on the location or the user's demand. A smart buffer management is also developed to suffer the 1-second handoff delay. In our experiment, we can play audio and video streams smoothly even when handoff happened.

PROTOTYPE AND EVALUATION

The proposed campus guidance system is a small testbed and showcase of our research

projects at intelligent transportation systems. We have developed an AutoPC prototype as showed in Figure 6.



Figure 6. A picture of the developed prototype

Hardware Platform

The AutoPC was customized using an industrial single board PC, 14.5cm * 10.2cm in size. It was equipped with a GPS receiver, 802.11b PCMCIA network adapter, LCD display, and touch panel. All software programs were stored in a 8MB flash ROM. The program size of the whole system, including the reduced single-user multi-task DOS-like Linux, bilingual MiniWin environment, mobile IP module, and integrated in-vehicle navigation and wireless multimedia streaming applications, is about 1.6 MBytes. Comparing with Windows CE-based AutoPC, we can reduce the requirements of RAM and ROM memories for AutoPC.

Demo Applications

Figure 7 shows the screen snapshots of our demonstration applications. With real-time GPS and wireless data receiving, the developed navigation application supports two map views: Figure 7(a) gives a usual 2-D view and Figure 7(b) gives a bird's eye view. A simple location-based query example is also given in Figure 7(c).

For MPEG-4 multimedia streaming, it can achieve 30 frames per second on an AMD K6-2/350 platform. Its bit rate is as low as around

800 Kbps for CIF (352 X 288) high resolution of MPEG-4 streaming. To run RTP-based MPEG-4 video streaming applications, a more powerful CPU would be required. Figure 7(d) gives a clip of a demo video streaming. Besides, it can play MP3 songs smoothly on low-end 486 platforms and the streaming bit rate is as low as around 150 Kbps.

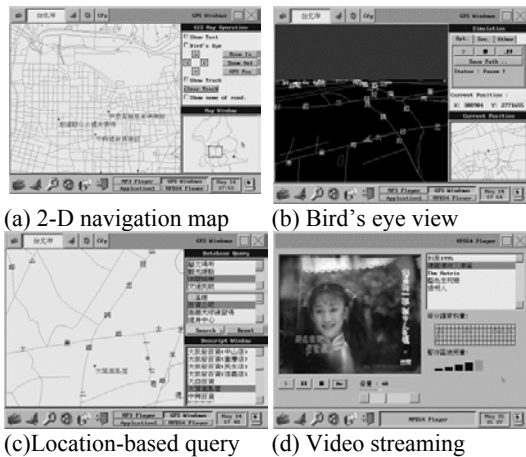


Figure 7. Screen snapshots of the applications

A Mobile IP Testbed over 802.11b Network

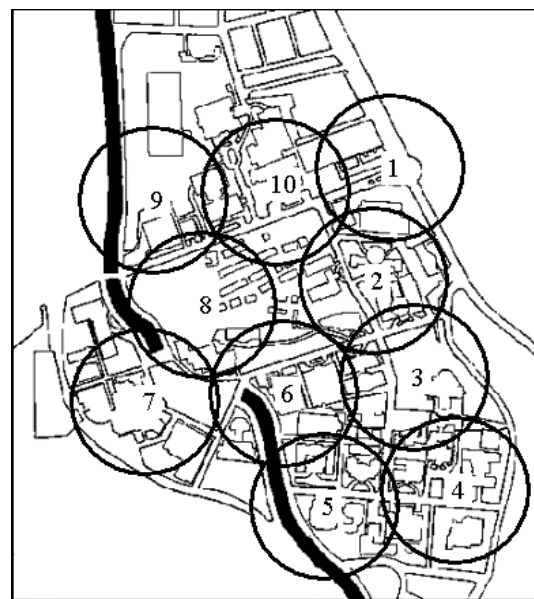
Testing our system in the environment of multiple 802.11b cells, the preliminary results showed that an in-vehicle AutoPC can run video streaming application smoothly on the road even when the car speed is up to 50 km/hr. The 1-second handoff delay can be suffered by smart stream buffer management.

In order to explore more mobile computing and wireless navigation issues, we are deploying a mobile IP testbed with 802.11b network covering the major roads in the campus of Academia Sinica. As showed in Figure 8, ten 802.11b access points as the base stations are expected to be enough for the testbed. Each access point equipped with outdoor antenna would be placed near the window of the building and connected to the existed IP backbone in Sinica. When a visitor enters the main gate, he can be navigated to his destination and given brief introduction to the building near him.

CONCLUSIONS

In this paper we examine the design of an AutoPC that supports regional navigation and location-based multimedia services on

broadband mobile Internet over wireless 802.11b network. The layered architecture of the AutoPC with a MiniWin windows framework supports portability, interoperability and extensibility to applications and platforms. In addition, customizing the software for mobile and navigation services with open technologies also helps us reduce the resource requirements of hardware. Learning from these experiences, we can then develop a new-generation and cost-effective AutoPC in a connected society.



Base Stations

1. Main Entrance
2. Computer Center
3. Institute of Physics
4. Fu Ssu-Nien Library
5. Institute of European and American Studies
6. Institute of Information Science
7. Center for Academia Activities
8. Institute of Statistical Science
9. Institute of Astronomy and Astrophysics
10. Institute of Molecular Biology

Figure 8. Places of the access points in the guidance system of Academia Sinica

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