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RESEARCH IN THE UNIQuE ENVIRONMENT: MOBILE MULTIMEDIA SERVICES

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The future will bring many different network technologies, different operating systems, and different communication devices. Each system has its specific advantages and disadvantages. Especially in the mobile and wireless environment, a large variety of communication systems exists (GSM, WLAN, DECT, IrDA etc.). Driven by the requirements of communication infrastructures for traffic scenarios (cars, trucks, trains), we implemented several advanced systems on our flexible UNIQuE (Universal Networking Infrastructure with Quality of service Enhancement) testbed. Research topics are operating system support for mobility, proxy architectures, differentiated services, hard/soft Quality of Service (QoS), Mobile IP, and the Wireless Application Protocol (WAP). This paper gives an overview of the architecture and describes one research topic, the implementation of simple user interfaces and integrated QoS mechanisms in more detail.

Keywords: Operating System, Multimedia, Quality of Service, Mobile Computing, Proxy, Wireless Network

1 INTRODUCTION

History shows that there is not a single networking technology covering all aspects of communication, the future will bring even more technologies. Examples are broadband infrastructures based on ATM or IP over Sonet, LANs based on Ethernet, wireless LANs according to IEEE 802.11, infrared access using IrDA, mobile and cordless phone systems (GSM, D-AMPS, DECT, PHS etc.). New technologies include Personal Area Networks using, e.g., Bluetooth [1], scalable QoS provisioning in the Internet with Differentiated Services [2], and advanced protocol stacks for wireless and mobile communication (e.g., Wireless Application Protocol, WAP [3]). A single technology can never cover all aspects of communication. While in wired communication we could think of an ideal world with fiber to the desktop and powerful communication systems, the wireless and mobile domain puts several limitations on communication systems. Portability of devices restricts the performance, mobility poses new requirements on QoS support, and wireless access limits the bandwidth (particularly at a high relative speed of senders or receivers).

Our current application scenario includes the establishment of an integrated communication infrastructure for cars, trains, and trucks to increase the efficiency of traffic by means of communication. The goal of this research is to provide a reliable networking infrastructure that integrates different networking technologies. A car could receive broadcasted multimedia data via DAB (Digital Audio Broadcasting), duplex communication is achieved by mobile phone systems in the wide area, via wireless LANs in cities or, e.g., at service areas. Highly reliable real-time ad-hoc communication networks will be implemented between the vehicles. This simple example already motivates research in the areas of operating systems and applications for portable devices, communication protocols adapted to a mobile and wireless environment, and QoS provisioning in heterogeneous networks.

In the next section we present some research projects related to wireless networks, mobile communication, and portable devices. The third section describes the UNIQuE architecture, our open, flexible, and heterogeneous architecture used for our research. As one example, the fourth section focuses on a simple user interface and operating system integration of adaptive communication systems providing QoS. Adaptive systems with a minimum of necessary user interaction are essential for the use in, e.g., cars. Network characteristics change rapidly and the user has to concentrate on the traffic. Thus, the system has to adapt to the current delay, bandwidth, network system, application etc.

2 STATE OF THE ART

Several research groups focus on the provision of efficient communication systems for mobile and wireless networking. The following two examples provide proprietary toolkits that allow for the creation of applications in the mobile environment.

2.1 The Mobiware Toolkit

In order to make mobile applications capable of responding to time-varying wireless quality of service conditions, an open and active programmable mobile network has been built at the Columbia University, controlled by a middleware toolkit called *mobiware* [4]. Openness is achieved by supplying new mobile signaling, transport and adaptive QoS management algorithms for the hardware devices in the mobile network, i.e. mobile devices, access points and mobile-capable switches/routers. Active means that adaptive QoS algorithms can be introduced using Java objects that are injected on the fly into devices. Programmability is based on new adaptive services using distributed object computing technology, e.g., the Common Object Request Broker Architecture CORBA. The mobiware architecture, therefore, covers the complete communication subsystem from transport to medium access layer, separated between data transport and signaling/adaptation management. Although this architecture is a broad approach to support for adaptive mobile networking, it has one big disadvantage: due to changes required for its openness, the architecture requests hardware devices being enhanced with new signaling and transport algorithms. This might be applicable in a small, limited environment but cannot be extended to regional or wide area networks supplied by numerous concurrent network providers.

2.2 The Rover Toolkit

Similar aims are covered in the *Rover* toolkit, a project carried out at the MIT Laboratory for computer science [5]. This toolkit provides mobile application developers with a client/server distributed object model that isolates mobile applications from the limitations of mobile communication systems. Therefore, it supports both mobile-transparent applications (using proxies) and mobile-aware applications. Main concepts of the Rover toolkit are relocatable dynamic objects, which can be dynamically loaded into a client or server computer to reduce client-server communication requirements, and the queued remote procedure call for non-blocking remote procedure calls even when being temporarily disconnected from the network. This approach leads to reliable applications in a mobile environment but these applications have to be re-implemented using the Rover toolkit. Hence, no "standard" applications can be used in the Rover environment.

The main problem of these projects and many others is the use of new protocols, applications, or even hardware. We rather believe in the integration of existing protocols, networks, and applications, and favor an evolutionary approach.

3 THE UNIQuE ARCHITECTURE

In order to evaluate new concepts, to run test scenarios, and to integrate advanced communication hardware, the UNIQuE research group installed a flexible, heterogeneous, and open testbed (see Figure 1). The bottom half shows the configuration for Differentiated Services (DiffServ [2], [6]) related research. This part of the testbed realizes a DiffServ domain and comprises several end-systems which can generate load. Three Linux-based software routers constitute the DiffServ domain. We have implemented a First Hop router, an Interior Router, and a Border router on high-end PCs. While the lower part of the testbed is used for research related to "soft" QoS in the Internet domain, the testbed has in addition a connection to the national ATM backbone. Thus, we can also provide "hard" QoS guarantees, set up virtual LANs with remote test partners, and evaluate the integration of ATM/IP networks.

The gateway to the wireless domain is realized by a PC running Linux. This gateway is not only used for simple interconnection of the wireless network with the wired network. Furthermore, it realizes a Foreign Agent as required for Mobile IP [7] and acts as proxy or cache as needed for different TCP extensions developed for the wireless domain (I-TCP [8], snoop proxy [9], M-TCP [10]). A broad choice of wireless connections is available. Low performance and short range connection is realized via infrared (IrDA) and DECT (Digital Enhanced Cordless Telecommunications), an IEEE 802.11 compliant WaveLAN II network provides data rates up to 2 Mbit/s (10 Mbit/s in a proprietary mode[11]). For experiments with wide area networks, GSM (Global System for Mobile communications) and DAB (Digital Audio Broadcasting) adapters are available [12]. While the current GSM systems only offer up to 14.4 kbit/s, the next generation provides data rates up to 115.2 kbit/s. DAB offers an additional, cost effective means of data transportation. The available bandwidth is 1.5 Mbit/s over a shared radio channel; however, DAB only works unidirectional.

This short listing of the available components shows the very heterogeneous character of the testbed. In addition, technologies like DAB, but also certain other radio technologies, introduce very asymmetric communication links. We do not believe in a homogeneous network environment. Especially in the wireless domain, each technology has its advantages and disadvantages (e.g., GSM works bidirectional, but only up to 250 km/h, whereas DAB works up to 900 km/h, but only unidirectional – trains go faster than 300 km/h already today). Thus, one of the main tasks is the integration of different networking technologies as can be studied with our testbed in addition to the combination of ATM/IP and wireless/wired networks.

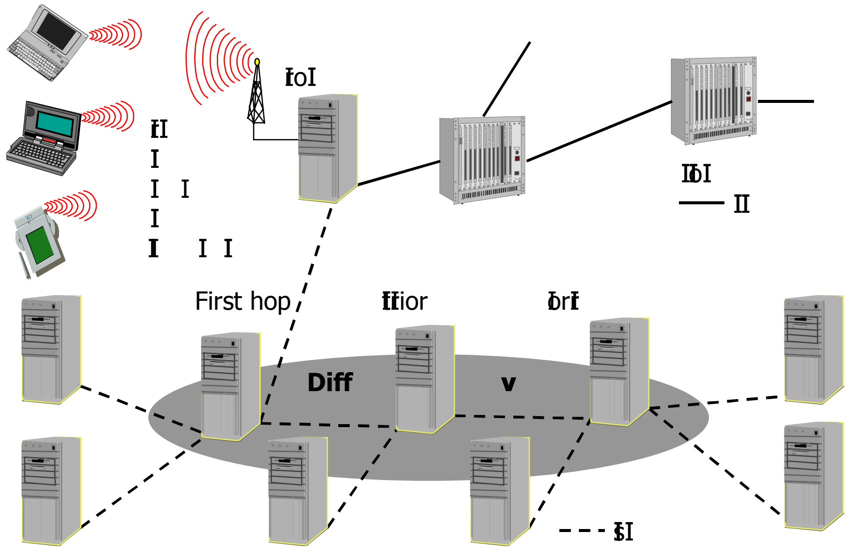

Figure 1: The UNIQuE testbed

Motivated by the application scenario described in the beginning, we are working in the following research areas using the UNIQuE testbed.

3.1 Digital Audio Broadcasting

Although DAB only provides unidirectional communication it is a very cost-efficient means of data distribution. For example, users can request a web page via GSM (only some bytes are needed for a request). The page is then received via DAB. Furthermore, pages of common interest (news, weather, sports) could be broadcasted in a cyclic fashion. The receivers can then cache these pages and provide them to the user upon request without delay.

3.2 Handover

Today's mobile phones already perform handover between different base stations within the same system. New generations will also allow to change the network technology without interruption. One research topic is the provision of QoS for different networks and during handover. Communication systems and applications have to adapt to different bandwidths and delays. Furthermore, the networks have to reroute packets, change resource reservations for QoS provisioning, and perform authentication for security relevant communication scenarios. The UNIQuE architecture comprises a proxy and end-systems that can switch between different wireless network technologies while still maintaining, e.g., TCP connections with a certain QoS.

3.3 Proxy

Proxy-based adaptation is an attractive research area at the moment. Several projects apply infrastructural proxies to adapt to network and client variation; examples are the programming model for internet services TACC (which stands for the basic actions *T*ransformation, *A*ggregation, *C*aching and *C*ustomization) [13] or the framework for image transcoding proxies developed at the IBM T.J. Watson Research Center [14]. Within our testbed described in the beginning of this section, we also want to apply the concept of proxies in the UNIQuE architecture. The initial point of research is a proxy architecture based on CORBA, which allows for flexible and adaptive insertion of proxy objects in a given data stream from a server to a mobile client [15]. This architecture is currently being integrated into our testbed.

3.4 Operating System

Current wide spread operating systems, e.g., Windows or Linux, do not consider user preferences for scheduling running applications in an adequate way. On the one hand, they do not offer a suitable user interface, on the other hand the kernel of these operating systems only supports few mechanisms for taking the QoS requirements into account. For our UNIQuE architecture we designed and implemented such an easy-to-use interface in a first step for local systems as described in chapter 4. This approach is of special interest for mobile handheld devices with restricted computation capabilities and varying networking QoS. The integration of this concept in our testbed allows us to expand and evaluate our mechanisms in the distributed and mobile environment.

3.5 WAP

The Wireless Application Protocol (WAP [3]) comprises protocols (Transport, Session, Security), application environments, telephony integration, and a markup language (Wireless Markup Language, WML) for wireless and mobile devices. The UNIQuE environment is an ideal base for experiments using this new architecture in addition to the evolutionary approach with TCP/IP and traditional browsers, HTML, and HTTP. Research topics are the interworking of WAP and Internet protocols, gateways for content transformation (HTML to WML), and transaction oriented applications on top of WAP.

3.6 Diffserv

The integration of Quality of Service (QoS) aspects is an overall topic in the UNIQuE environment. It concerns both end systems and network nodes. In the network area, renowned architectures like the RSVP-based Integrated Services model in IP networks [16] tend to be very complex. The Differentiated Services (DiffServ) architecture [2], [6] provides simpler mechanisms to differentiate the service levels of aggregated streams, resulting for example in a lower drop priority for some streams compared to the default best-effort service. In the UNIQuE testbed we currently examine the integration of common end systems into a DiffServ network. In order to allow a simple differentiation of service quality in the end systems, applications should be enabled to set the DiffServ codepoints instead of the first hop router.

4 IMPLEMENTATION OF A SIMPLE USER INTERFACE

As mentioned above there is a lack of suitable QoS support from operating systems to users and applications. Once an application is started, it equally shares the available computation time with all the other applications currently running, but it does not take into account that the user might prefer one application over the others. Our goal was to realize powerful and transparent mechanisms in the kernel that are hidden behind an intuitive user interface. Of course, existing applications have to be kept executable, and thus transparency is needed.

4.1 The Q-Button as an easy-to-use interface

The user should not deal with the specification of technical parameters, therefore we introduce the Q-Button for the interaction between the user and the application. This button resides in the window title bar of *every* running application in the system. Figure 2 shows a screenshot of such a window title bar. Thus, our QoS extension in Linux can also be used for existing applications without having to modify them.

If the user requests more QoS support for an application, she or he just clicks on the Q-Button; pressing the shift key while clicking decreases the QoS requirements for this application. The following steps are performed once the Q-Button is clicked. First, the corresponding application will be noticed that the user requests more or less quality for this application. Provided that the application has implemented and registered a callback function it is able to adapt its application specific QoS parameters. As an example think of a video player that is able to adjust the frame rate. With this adaptation the scheduler of a resource (e.g., the process scheduler) is influenced in a suitable way via an interface to the kernel. The interaction between this application and the kernel is performed by an integrated feedback loop. If the application does not support the interface for notification (e.g., existing applications), a default value is used to influence the scheduler and, thus, the application receives QoS support as requested via the scheduler.

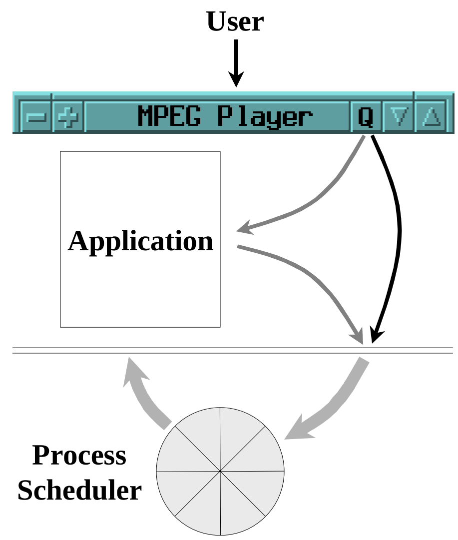

Figure 2: QoS support using the Q-Button

The strict separation of interfaces and mechanisms form a flexible and expandable basis, because it allows the integration of other resources, e.g., the network interface. These aspects will be covered with the integration of our approach in the UNIQuE testbed. In order to show that our approach also makes sense for conventional applications, the following section describes first results with an existing application.

4.2 Experiences with existing applications

In order to demonstrate the effect of the intuitive pressing of the Q-Button let us consider two simple MPEG video players. Figure 3 shows the generated frame rates on an Intel Pentium 133. Video player 1 is started at $t_0 = 0$ and reaches rates of about 30 frames/s. When video player 2 is started at $t_1 = 30$ s, the frame rate is halved (about 15 frames/s each). At $t_2 = 60$ s, the Q-Button is pressed in favor of video player 1, and at $t_2 = 90$ s, the Q-Button is pressed in order to decrease the frame rate of video player 2. Both actions result in a higher frame rate and thus a better quality for video player 1 at the expense of video player 2. The user can therefore dynamically change the focus to the application in which he or she is most interested in at the moment.

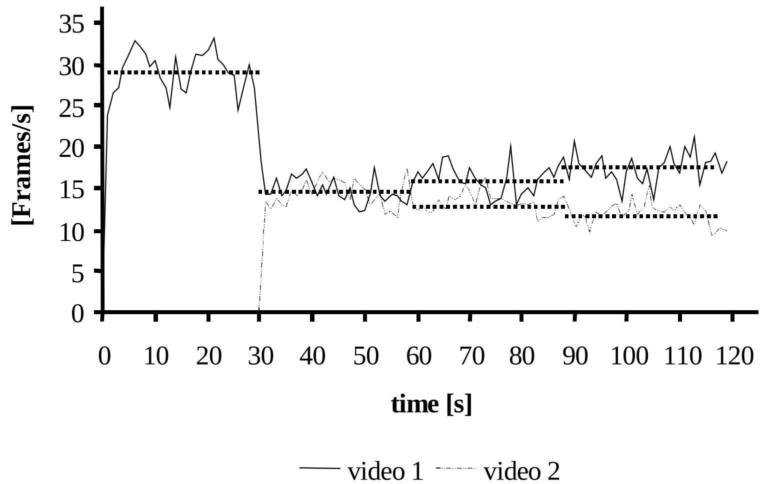

Figure 3: Adaptation of frame rates to user requests

5 CONCLUSION

Mobile communications will change networks and applications in many ways. As we do not believe in the single technology that covers all aspects of communication, the integration of different technologies and the seamless provision of a certain QoS will be major topics for the success. The UNIQuE research team focuses on operating systems, applications for portable devices, communication protocols adapted to wireless networks, and the QoS provisioning in heterogeneous networks. As it is often not possible to control the characteristics of a network or to adjust the behavior of applications manually, this paper showed one example of adaptive applications with an intuitive and minimalistic user interface.

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