Wireless Multimedia Networks : 5G base connectivity

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ABSTRACT

Advances in information technologies have made it possible to have Personal Information Service, i.e., personalized multimedia information available anywhere, anytime. Such ubiquitous access requires that a portion of the underlying network infrastructure be wireless. Therefore, a number of challenges associated with operating a wireless multimedia network must be overcome. In this paper, we have identified these challenges and some solutions.

1 Introduction

With the affluence that comes with economic developments and technological advances, citizens around the world will demand personalized, on-demand, high quality information services, or Personal Information Service (PIS)[8]. Such services are characterizedby beingpersonalized, i.e., tailored to the individual user, and ubiquitous, i.e., available anywhere, any time. For example, while in the past we are satisfied with broadcast TV, in which millions of people watch the same programs, now we want videoon-demand (VOD), which allows one to choose the video at the desired time, and to interact with it. Another example is Personal Communication Service (PCS)[11]. Each user is assigned a personal telecommunication number, and may be reached anywhere in the world. In addition, each user will be able to access a variety of communication services on demand. The Internet provides yet another example of such personalized service, with each user customizing his access through a series of mouse clicks to get the information desired. Advances in computer, communication, consumer electronics, and information technologies in recent years have actually made such services available today to selected people. However, to make them available to the masses we must overcome a number of challenges. In particular, we must develop the infrastructure and protocols to support such services. This infrastructure will be a network of networks, including the existing public telecommunication networks, satellite networks, wireless networks, the Internet, etc. We have to study each such network not only as an independent entity, but also as a collection. The underlying protocol will most like be Internet Protocol (IP) based.

In Section 2, we will describe some applications of wireless multimedia systems. Enabling technologies of such applications, and the challenges to be overcome before such systems will be widely deployed will be included in Section 3. We conclude in Section 4.

2 Applications

Multimedia integration and real-time networking create a wide range of opportunities for multimedia applications. According to the different requirements imposed upon the information, communication, and computing subsystems, distributed multimedia applications may be broadly classified into three types [10]: interactive video (ITV), tele-cooperation, and hypermedia applications. ITV requires very high transmission rate and stringent quality of service (QS) guarantees. It is therefore difficult to provide such broadband services over existing low speed wireless networks. ITV typically demands point-to-point, switched connections. Bandwidth requirement is asymmetric in that the bandwidth of the downstream channel which carries video programs from the server to the user is much higher than that of the upstream channelfrom the user to the server. Tele-cooperation requires multicast, multipoint, and multiservice network support for group distribution. In contrast to the strict requirement on the video quality in ITV applications, tele-cooperation applications, such as videophone and desktop conferencing, allow lower picture quality, and therefore lower bandwidth requirements. It is possible to provide such services with the existing wireless networks. Hypermedia applications, such as world wide web browsing, are retrieval services, and require point or multipoint to point and switched services. As with tele-cooperation applications, hypermedia applications require powerful multimedia database systems, with intuitive user interface such as visual query support, and content-based indexing and retrieval. Due to the huge volume of data transmitted, the existing wireless infrastructure can only support hypermedia applications in very limited forms. For example, while it is possible to surf the web with a notebook computer connected to a cellular system, the user will suffer excessive waiting while files are downloaded from the remote servers to the portable device through the slow wireless link.

The Wireless Multimedia Forum defined the following wireless multimedia service, namely, streaming multimedia (on-demand/live/scheduled), downloading multimedia, uploading multimedia, multimedia messaging (e.g. video email), wireless video surveillance (e.g. wireless video camera), real-time multimedia communication (e.g. videophone, videoconferencing), and interactive multimedia games. Again, each service will impose very different requirements on the underlying system infrastructure.

Perhaps the key application of wireless multimedia service will be M-commerce, which may be defined as the transacting of business on a non-proprietary wireless network, such as the existing cellular radio networks and 3G networks. We have chosen to exclude wireless systems that utilize a dedicated wireless network running proprietary protocols, because we believe that for m-commerce to flourish, the users must have ubiquitous access to this network infrastructure, and it will be difficult for a proprietary system to claim ubiquity. At the same time, our definition will include non-cellular wireless systems such as Wireless Local Area Networks, Bluetooth-based, and even satellite-based networks using non-proprietary protocols. M-commerce may also be more generally defined as applications and services built on non-proprietary wireless network platforms. In this sense, the more narrowly defined m-commerce may be included as one of the applications, and other applications, such as remote monitoring and telemetry, information dissemination, etc., will also be included. In this paper, we will use the more general definition. No matter which definition you fancy, m-commerce is going to be huge. According to the Gartner Group, the global market for wireless data services will be over USD 50 billion by the year 2004, with 40% of the business-toconsumer e-commerce transactions outside North America conducted over a mobile phone. It is also estimated that there will be over one billion wireless subscribers worldwide by 2003 (source: Dataquest). One of the strongest growth regions is China, which has recently surpassed the US as the country with the largest number of mobile subscribers. The Asia Pacific region is expected to become the leading region for wireless data services by 2004.

Of course, an explosive growth in cellular telephonymay not necessarily translate to successful m-commerce. We believe m-commerce will be successful because[9]: (1) It is a more cost-effective way to conduct business. It saves money by providing ”just-in-time information delivery.” (2) The ”just-in-time” feature of mobile communications will introduce a variety of new services. (3) The trend in the telecommunication world is towards ”personalized” information service.

3 Enabling technologies and challenges

The development of computing, networking, and consumer electronics technologies have made it possible to have wireless multimedia systems. In fact, today we can have limited forms of such service. A personal digital assistant (PDA) connected to a cellular phone with a modem will allow us to send and receive email. There are also various forms of wireless data services available. Such services, however, are very limited in terms of data rates, and hence the form and variety of services available. A number of problems must be overcome before the large scale deployment of wireless multimedia systems.

3.1 Limited bandwidth

Perhaps the most difficult problem is due to the wireless medium itself, which is limited in bandwidth, and suffers from such transmission problems as fading, multipath, etc. Error correction or error detection with retransmission may be used to overcome the transmission errors, but this is at the expense of lower bandwidth utilization. Since the bandwidth is very limited to begin with, the hostile wireless medium does pose a very serious problem. To overcome this difficulty, there are three major approaches: (1) increase the amount of data transmitted in a given bandwidth, (2) minimize the amount of data transmitted, and (3) make more bandwidth available. Using a more efficient modulation scheme to fit more data within a given bandwidth is an example of the first approach. Developing more efficient multiple access schemes so that more users can share the same bandwidth is another. The deployment of smart antennas to provide space diversity and hence increase the capacity is also proposed. The second approach relies on various data compression techniques. For example, the JPEG (Joint Photographic Experts Group) standard uses the Discrete Cosine Transform (DCT) to compress an image, squeezing out the spatial redundancy within the image, while the MPEG (Motion Picture Experts Group) standard adds the motion compensation technique to further reduce the amount of data required by squeezing out the temporal redundancies from image to image in a video. The reader is referred to Li and Liao[10] for an introduction to the JPEG, MPEG, and other data compression standards. To further reduce the amount of data transmitted, MPEG-4[6] uses an object-oriented approach. Different parts of a moving image will be encoded separately, so that parts with less activities can be encoded using even less data. Finally, multi-resolution techniques may be used to tailor the amount of data transmitted with the amount of details required. The third approachmakes more bandwidth available for wireless communications. For example, the United States Federal Communications Commission (FCC) has released 300 MHz of unlicensed, ettiquetteless, radio spectrum for wireless data networks. This

Unlicensed National Information Infrastructure (U-NII) will allow the development of broadband, wireless multimedia access. The International Telecommunications Union's International Mobile Telecommunications-2000project has developed 3G standards which allow multimedia communications with bandwidth on demand and data rates of up to 2 Mbps.

3.2 Mobility Management

This deals with the difficulty due to the movement of the users. Hence we need to solve the problem of how to keep track of the movements of the user, and how to send data to a user who is moving around. To provide ubiquitous communications, the system has to track the movement of the user. One solution is to divide the whole system into location areas[11]. When the user enters a new location area, a location update transaction will be performed to inform the system of the new location. When a message is destined to this user, a database query is performed to find the actual location and the paging function is executed to alert the user. With this location information, a specified area is paged instead of the whole system. This is the solution used in cellular telephone systems. There are various ways in which these location update and paging functions may be performed, including manual and automatic location updates, static and dynamic paging areas, etc. to minimize the location update and paging traffic. To support roaming, i.e., allowing a user to continue to communicate outside of the user's primary subscription area, when a user visits a foreign area, the foreign system will send a location update message to the user's home subscription area. Any future calls to this roaming user will first be directed to the user's home location database, and then forwarded to the foreign system where the user is now located. A similar solution is used by the Internet EngineeringTask Force (IETF) Mobile IP Working Group[7] to allow portable computers to stay connected to the Internet, and to use the same IP address when it roams to a distant Internet site. Each site which allows its users to roam has a home agent, and each site which allows visitors has a foreign agent. When a mobile user visits a foreign site, it contacts the foreign agent and registers. The foreign agent contacts the home agent of the mobile and gives it the foreign agent's IP address. When a packet arrives at the home site addressed to this mobile, it will be forwarded to the foreign agent who will in turn pass it to the mobile. In addition, the home agent will pass the IP address of the foreign agent to the sender of the packet, and all future packets will be sent directly to the foreign agent.

3.3 Heterogeneous infrastructure

The key to successful wireless multimedia service development is the availability of a ubiquitous network infrastructure. Some believe this infrastructure is 3G. Others, pointing to proposals to connect whole cities with Wireless Local Area Networks (WLANs), and the fact that WLANs represent more mature technology and are implemented in the license-free band, believe WLANs will prove to be formidable competition for 3G. There are yet others who believe that Bluetoothbased networks will be the network infrastructure of the future. We believe the wireless network infrastructure will include each of these three components. We expect this infrastructure to be a network of networks, with a collection of wired networks at the core, and a number of access networks connecting individual users to the core. An access network may be a 2G or 3G network, a WLAN, a Bluetooth-based network, or even a satellite-based network. We have to study this infrastructure not only as an independent entity, but also as a collection. In addition, we have to tackle the problems which arise at the interconnections of such components, since each of them has very different characteristics. This calls for the development of adaptive protocols which adapts automatically to different applications and to the different underlying infrastructure. Thus, a movie-on-demand application will require much better video quality, and hence higher transmission bandwidth, than a video conferencing application. A communication session running on a path consisting of both wired and wireless components will need to determine automatically the medium it is running on, and adjusts the protocol parameters such as acknowledgment timeout, data rates, etc. In addition, such adaptation should be transparent to the users, so they can focus on the applications at hand, rather than worry about the characteristics of the particular components they are connected with.

Of course, the corresponding wireless access devices must be readily available. In fact, one of the reasons many believe m-commerce will be huge is the fact that in many parts of the world, more people own cellular phones than personal computers. If services and applications are available and affordable, it is expected that these users will use the mobile device as the preferred medium to conduct e-commerce.

3.4 Quality of Service Guarantees

Due to the problems inherent in wireless networks, deterministic service guarantees and bandwidth allocation, commonly used in wired networks, become inadequate in wireless networks. We believe that a more flexible service model which allows variable QS is needed. In [2], we propose a utility-oriented wireless adaptive QS model and a bandwidth allocation scheme which accounts for the users' QS requirements and actively adapts to the dynamics of the physical channel. There has been much work on wireless resource (bandwidth) management, focusing on multiple access and channel allocation[1]. Most of the previous work tackled one aspect of the bandwidth allocation problem,i.e. the dynamics of user requests. That is, resolving conflicts due to users' uncoordinated requests and allocating transmission slots or call channels appropriately to satisfy those requests. However, there is less research on adding explicit adaptive mechanisms to bandwidth allocation schemes to deal with the variations of wireless channels.

3.5 Wireless Security

To successfully deploy wireless multimedia service, a number of complementary technologies are required. One such technology is security. Wireless transmission is inherently insecure compared with wired transmission due to its susceptibility to eavesdropping. The users have to be assured that the information transmitted will be free from being intercepted, and modified by hostile parties. It is therefore important to have secure transmission technologies, such as those based on the Public Key Infrastructure (PKI). PKI not only encrypts the data so only the intended receiver can read it, but also allows authentication of the sender, and prevents unauthorized modifications to the transmitted data. The digital signature component of PKI also provides non-repudiation, i.e., once you have signed a document digitally, you cannot deny it. In fact, many governments have already passed electronic transaction laws giving digital signatures under PKI the same legal status as the traditional hand-written signatures.

The prevalent wireless LAN standard is IEEE 802.11, and the 802.1X draft standard[4] has been proposed to implement security in such systems.

3.6 Wireless Internet technologies

The prevalent network protocol on the network infrastructure is most likely going to be the Internet Protocol (IP). However, IP has been designed for wired networks, which are less error-prone, and enjoy more bandwidth compared with wireless channels. For example, one major IP protocol is the Transmission Control Protocol (TCP), which throttles the amount of data permitted to be sent by a particular user based on network feedback. In particular, if no acknowledgment is received for a transmission after a certain timeout, TCP assumes the network is congested, and reduces the amount of transmitted data. However, in a wireless network, lack of an acknowledgment within the timeout may be due to a variety of reasons, such as the long round-trip propagation delay to the satellite in a satellite-based system, or the retransmission delays of erroneous packets. There is much active research on how to adapt such protocols to the wireless environment. Another important technology is how to transmit multimedia data, especially video data, in a wireless network. One of the key attractions of future wireless systems such as 3G is the ability to transmit at relatively high speed compared to 2G systems, and to accommodate video transmissions. Despite the higher transmission speed of 3G systems, it is still inadequate for high quality video transmissions. Moreover, since future high speed networks will co-exist with existing lower speed networks, it is important to develop adaptive video transmission and compression schemes such that depending on the quality of the wireless channel, the right amount of video data will be transmitted to optimize the utility to the user. Again, this is an area of active research, and we believe solutions will be forthcoming.

3.7 Power Supply

The development of the battery has lagged far behind the improvements achieved in computational power and memory. There is an urgent need to develop lowcost, high-density, light-weight battery systems. In the meantime, a number of ways have been proposed to conserve the battery, such as using less power hungry components in the portable unit, moving the intensive computations to the backbone network from the portable unit[3], and such power-saving features as automatic blanking of the display after a timeout, activating different communication ports only when they are required, etc. I personally do not believe moving the computations to the backbone system is a good solution. Due to the frequent disconnections inherent in a wireless transmission medium, we should try to have most of the computations performed on-board, to minimize the number of data exchanges between the portable units and the system. Every data exchange increases the loading on the communication link, and more importantly, increases the possibility we may have inconsistent data due to transmission errors.

4. Conclusion

Advances in computing, communications, and consumer electronics have made it possible to have ubiquitous wireless multimedia service. To make such services widely available, a number of challenges associated with operating a wireless multimedia system must be overcome. In this paper, we have identified these challenges and some solutions. We hope that we have succeeded in stimulating other researchers to work on these challenges, and in time, we will have wireless multimedia services widely available.

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