A Scheme for Location-Based Internet Broadcasting and Its Applications

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ABSTRACT

In this article, a new Internet broadcasting scheme that combines the existing network-wide unicast protocol and a subnet-wide broadcast protocol is proposed. The proposed broadcasting scheme is appropriate for location-based push services and requires only a minor functional addition to the existing edge routers, base stations, or access points. To eliminate unnecessary broadcasting traffic, an efficient terminal-originated triggering algorithm for broadcast initiation is introduced. The scheme provides location-based information to mobile users without the need for protocol reconfigurations or prior knowledge of a user's location. We also discuss some potential applications of the scheme. Performance of the proposed scheme has been evaluated and selected results arepresented in this article. The evaluation shows that the broadcasting scheme significantly reduces the network traffic and the server load.

INTRODUCTION

With the convergence of wireless communications and wireless Internet-based networks, wireless Internet broadcasting technologies and services have been extensively developed. For Internet-broadcasting service, multicasting technology is the best solution. However, IP multicasting has not been deployed widely due to the lack of multicasting nodes in the Internet and the fundamental concerns related to scalability, reliability, and congestion control [1]. Therefore, instead of multicasting, unicast protocol often has been employed to deliver broadcast datagrams one-by-one to individual users. However, as the number of users increases, so do the network traffic and the server load. The increase in the network traffic and server load can be so severe as to potentially bring down broadcasting servers.

To overcome this problem, tunneling schemes between multicasting nodes and overlay architecture have been proposed [2, 3]. These schemes combine unicast and multicast protocols to bypass legacy protocols and to provide multicasting services to an application. Due to the wide range of wireless network types and because of the importance of the broadcasting services in such networks, several types of broadcasting schemes were developed for wireless systems. For cellular networks, cell broadcasting service (CBS) [4] has been used for broadcasting information to anonymous users within a cellular system. However, CBS is based on proprietary air interface protocols, not the Internet protocol, and is thus of limited use. IP multicasting is available in the Universal Mobile Telecommunications System (UMTS) standard and partially supports the Internet multicasting protocols. However, in UMTS, multicast data is distributed to the terminals individually on point-to-point air interface channels, leading to an inefficient use of the cellular spectrum. IP Datacasting [5] and Multimedia Broadcasting and Multicasting Service (MBMS) protocols are expected to be commercialized in the near future. IP Datacasting uses Internet multicasting protocol for delivery of Internet datagrams from content provider to radio stations. The protocol encapsulates the datagram by using existing digital broadcasting protocols, such as *MPEG-2* and digital video broadcasting (DVB). MBMS also has been adapted to wireless Internet-based networks, such as the 3GPP release 6 and *WiBro* [6,7]. It supports the broadcasting mode and the multicasting mode in which users join a channel to view its content. The latter two schemes employ Internet multicasting protocol for the IP datagram delivery from content server to wireless network gateway. Thus, to operate these schemes, the service providers must deploy a multicasting infrastructure in the Internet. In particular, complex protocols between terminals and gateways are required to support multicasting function in the mobile network. Overall, the current multicasting schemes and the current multicasting addressing are mainly focused on the *pull* operation of the broadcasted data.[1] Additionally, when a particular piece of information is required, a user must either know a priori the URL of the sought information or to search for specific Web site addresses. Moreover, the users also must manipulate the settings of their terminals to function properly in a particular mobile environment.

In this article, a new Internet broadcasting scheme is proposed and its advantages and performance are discussed. Also, some anticipated application services are outlined. Using the proposed scheme, with only a minor functional

[1] *In the* pull *operation, the destination (i.e., the user, in our case) originates the process of data delivery to the destination. In contrast, in the push operation, the source (i.e., the server, in our case) originates the data delivery process.*

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addition to base stations, access points (APs), or edge routers, the broadcasting service provider can reduce the network traffic volume and the server load. Moreover, the users are not required to explicitly search for or request information that is specific to a current user's location.

THE LOCATION-BASED IP BROADCASTING TECHNOLOGY

The IP specification defines that the IP address of all 1's represent subnet-level broadcast; that is, such datagrams are delivered to all the nodes on the subnet [8]. A subnet-level broadcasting datagram cannot reach nodes beyond the subnet; otherwise, it would result in network-wide flooding and severe network congestion. Subnet-level broadcasting has been used mostly for signaling in the subnet, such as the BOOTstrap Protocol (BOOTP), rather than for user data broadcasting operations.

Using a unicast protocol, a broadcasting server in the Internet can carry broadcast data to an edge router, a base station, or an access point that is located at the edge of the Internet and is connected to a subnet of terminals. Then, such an edge router, base station, or access point can broadcast the data to all the nodes in the subnet using subnet-level broadcasting. Thus, the proposed broadcasting scheme integrates subnet-level broadcasting operations with unicast routing, where the unicast routing is from a server to an edge router with a unique IP address.

Figure 1 shows the network configuration of the proposed location-based IP broadcasting scheme for a wireless local area network (WLAN). WLANs have been deployed extensively worldwide at a fast rate, with almost all of the APs connected to the Internet by a wired LAN or by an x-digital subscriber line (xDSL). Since APs are non-mobile and are assigned unique IP addresses for operation and maintenance purposes, such IP addresses identify the location of the AP. In the proposed scheme, a broadcasting server maintains the list of IP addresses and their corresponding location information. First, using unicast routing, the broadcasting server sends the broadcasting datagram to a destination IP address that corresponds to a specific location. The AP with that IP address receives the datagram and by reading the protocol number and the port number, the AP identifies the datagram as a broadcasting datagram. For broadcasting services, User Datagram Protocol (UDP) should be used instead of TCP, and a new port number should be defined for this application. After the datagram is identified as a broadcasting datagram, the AP replaces the destination IP address of the datagram to all 1's, recalculates the IP datagram checksum field, and resends the datagram on the local radio subnet. When the datagram is sent to the subnet, the destination media access control (MAC) layer address also should be set to the broadcast address for channel efficiency in the subnet. For Ethernet and for WLAN, the broadcast address is all the 48 bits set to "1" [9]. On the terminal side, all the associated wireless terminal receivers in the radio zone of the AP receive the MAC frame and bypass the

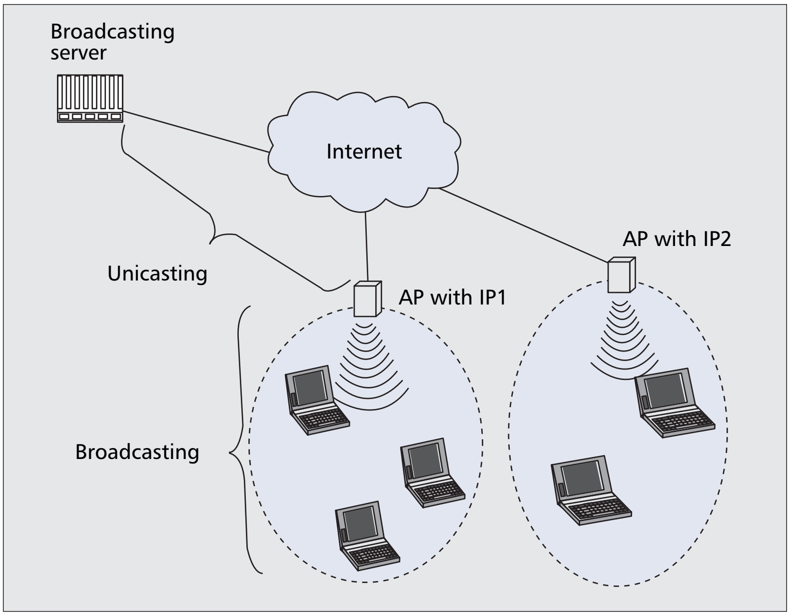


Figure 1. *The network configuration of the location-based IP broadcasting scheme.*

datagram to the IP layer because of the broadcast MAC address of all 1's. The IP layer passes the datagram to the UDP layer without filtering because of the broadcast IP address of all 1's. Then, the broadcast data packet finally is delivered to the application according to the predefined UDP port number. The scheme allows the user to receive the broadcasted data with the information related to the user's location, without requiring that the user know the IP address of the data server.

To implement the above Internet location-dependent broadcasting, edge routers, base stations, and APs must be able to translate IP addresses; in particular, the base stations or the APs should identify the broadcasting datagrams and replace the destination IP address of the broadcasted datagrams to the IP broadcasting address of all 1's. The checksum, which covers the IP datagram header, must be recalculated, and the IP datagram is then broadcasted on the subnet with the subnet MAC-layer broadcast address.

With the proposed scheme, an IP datagram broadcast to the subnet does not require the knowledge of the local subnet IP address or the IP addresses of the nodes in the subnet. All of the nodes in the subnet can receive the IP datagram without any prior configuration of parameters[2] of the nodes or of the broadcasting server. Moreover, there is no need for registration to receive the location-based information. The scheme operates in the *push* mode, similar to broadcasting radio stations; that is, users turn on their terminals and can listen to a particular channel. As an IP address is not required at the receiver, an IP address assignment protocol, such as Dynamic Host Configuration Protocol (DHCP) is not required either, and the scheme supports unlimited numbers of receivers in a subnet. Also, as the server sends broadcasting datagrams — not to each receiver — but only to edge routers, base stations, or APs, the broadcasting traffic and the server load are reduced consider-

[2] *Examples of such parameters include the IP address, the subnet mask, the gateway address, the domain name server address, and the address of the Web site of interest.*

The proposed scheme implements the push type of services using broadcasting technology, so neither users, nor service providers must know the users' locations, eliminating the problem of guarding the privacy of the users' location information.

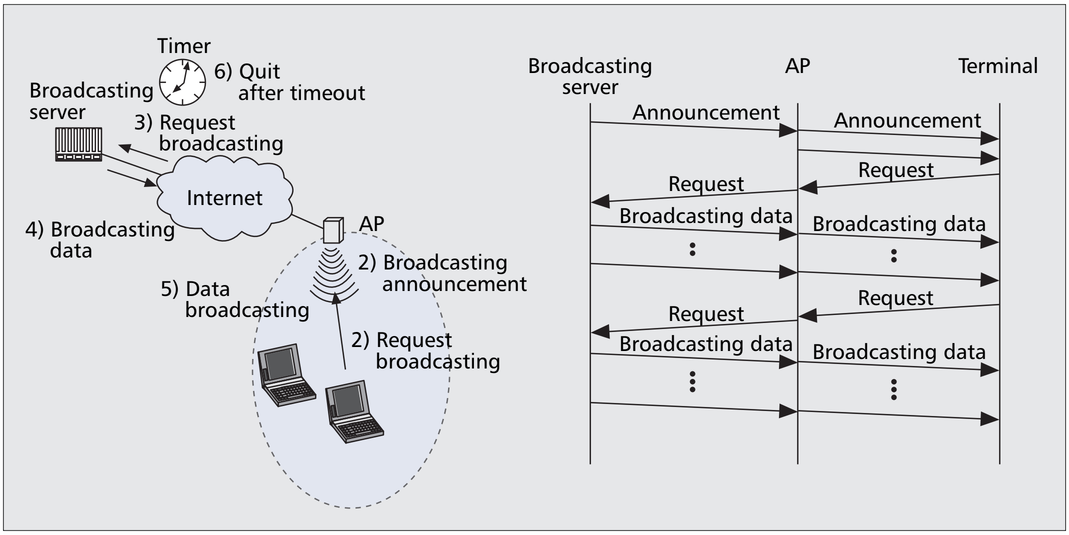


Figure 2. *The procedure of location-based IP broadcasting with triggering datagrams: a) information flow among the network elements; b) related timing diagram.*

ably. For location-based information and traffic information services, the broadcasting contents should depend on the location of the base station or the AP. In contrast, traditional multicasting schemes, which provide the same contents to all the base stations or APs, are unable to support such location-based broadcasting services. By comparing the proposed scheme with the current Internet broadcasting services using unicast protocol, not only the Internet traffic is reduced by the proposed scheme, but also the local traffic in a subnet or a cell is considerably lower. Finally, as already pointed out, the proposed scheme implements the push type of services using broadcasting technology; so neither users, nor service providers must know the users' locations, eliminating the problem of guarding the privacy of the users' location information. Finally, to ensure security, IPSec protocol should be used between the broadcasting server and the APs.

TRIGGERING LOCATION-BASED BROADCASTING

The proposed location-based IP broadcasting scheme is simple and is easy to implement and use. However, even if there is no user in a radio zone, the server would still send the data to the base station or the AP, which results in some inefficiency. To avoid this unnecessary traffic, we propose a terminal-originated triggering method (depicted in Fig. 2) for use in conjunction with the proposed broadcasting scheme. An AP broadcasts announcement (advertisement) messages repetitively to the mobile terminals in its radio zone. When a terminal enters the radio zone and receives the announcement message from the AP, the terminal transmits a broadcast request datagram (which we call the *triggering request datagram*) to the AP, with a destination IP address of all 1s using the UDP protocol, and on a predefined port number. The AP receives and recognizes the triggering request datagram and forwards it to the server by unicast routing. When the server receives the triggering request datagram, it starts a timer and begins sending the broadcasting data to the AP. In the absence of future triggering datagrams from the AP, the server ceases to send the broadcasting data after the timer expires. Thus, for a terminal to continue to receive broadcasting data, the terminal must periodically send the triggering datagram to the AP.

The AP periodically sends out its set-up information, which is constantly received by the terminals and which consists of the AP announcement messages, AP identification, the list of current or available broadcast channels, and the remaining time until timer expiration (of each broadcast content). When a terminal moves from one location to another, by listening to the set-up information of a local AP, the terminal can recognize that it is now in the coverage of a new AP. If a required broadcasting channel is not among the currently broadcasted channels, then the terminal sends a triggering request datagram. This *subscription* method, although it shares some similarities with the *registration* of multicasting protocols, is a simpler scheme and is not required to convey multicasting addresses (or other related signaling information) or mobility management procedures on the network side. By employing the optional triggering datagrams with added complexity, the unnecessary broadcasting traffic can be eliminated, and the network utilization can be improved. Finally, continuity of reception is maintained by the mobile terminal requesting the same broadcasting data upon changing its AP radio zone.

When a server does not receive a triggering datagram before a timer expires, it broadcasts a short extension of the timer to all the terminals on the subnet as a warning of imminent termination of the broadcasting channel, during which time any terminal that is still interested in receiving the channel should respond with a triggering datagram. To avoid an avalanche of triggering datagrams, sending the triggering datagrams should be done in a randomized manner (i.e., adding random delay before a transmission). After a triggering datagram is received, the AP will advertise the increase in the remaining timer value. This should signal to all the other terminals not to send their triggering datagrams in this *cycle*. Afterward, the terminal that sent the trigger datagram should continue sending the triggering datagram periodically before the timer expires. When this terminal leaves the AP coverage, the continuity of the broadcasting content is ensured by the execution of the short extension to the timer, the broadcast of the warning message, and the random triggering datagram mechanism.

MULTICASTING FOR LOCATION-BASED IP BROADCASTING

As the multicasting services become commercially available, in the case when multiple base stations or APs[3] are to receive the same location-based content information, broadcasting data from the broadcasting server can be delivered to each AP using the Internet multicasting protocols. The operation of the broadcasting delivery and the triggering datagrams for multicasting is very similar to the case of a single AP, with the exception that now the AP would identify multicast datagrams with the broadcast information, rather than unicast datagrams. Nevertheless, the operation of the AP remains essentially the same.

The advantage of this scheme is that it exploits the inherent benefit of Internet multicasting in reducing the amount of traffic; that is, the broadcasting server sends the datagram just once, and the multicasting routers automatically copy and route it to the relevant APs, as is shown in Fig. 3. Of course, if each AP must broadcast different content, then the use of Internet multicasting in delivering the content from the broadcasting server to the APs is no more efficient than the previously described unicast routing.

To incorporate the triggering datagrams, each AP receiving a triggering datagram for a specific content registers for the multicasting group using the IGMP (Internet Group Management Protocol) for IPv4. This is an easy and an efficient way to provide wide-area broadcasting services using many APs without the use of a multicasting protocol at the terminal level.

REPETITIVE BROADCASTING AND DATA FILTERING FOR SELECTIVE DISPLAY

Some data do not change frequently, and it is often the case that such data must be received once by a terminal and then be refreshed only infrequently.

As a terminal moves throughout a radio zone of an AP, the time to receive any particular data is limited by the size of the zone and by the velocity of the moving terminal. For a user to listen to particular data at least once in a zone, the data should be broadcast repetitively in the zone. This can be implemented by storing the data in the AP, with the control fields of the header of the broadcasting data (to be used by the AP) including the broadcasting duration, the broadcasting data priority, and the rebroadcasting period. When the AP receives the broadcasting data, it first analyzes the header fields and stores the broadcasting data with the control fields of the header.

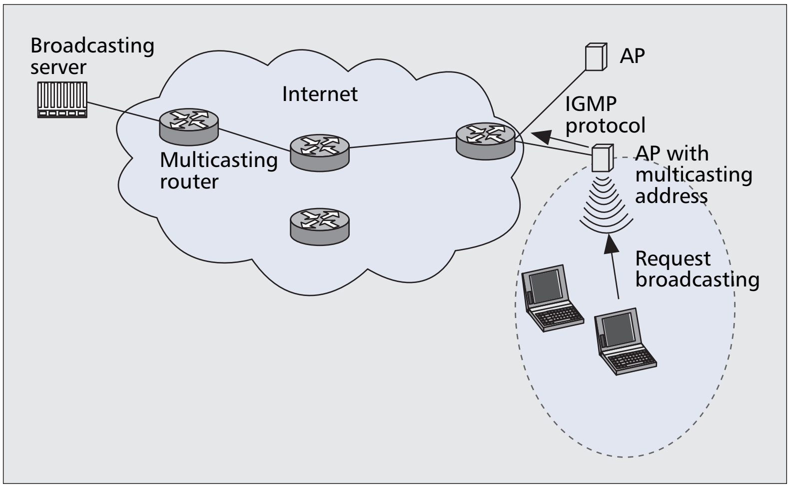


Figure 3. *The procedure for location-based IP broadcasting with triggering and Internet multicasting.*

The location-based broadcasting data sent from the broadcasting server to the APs would typically be of a very large volume. Moreover, such data could change periodically. The broadcasting data is not requested by terminals but rather pushed into terminals. If all such data were to be displayed on a terminal, it would be very difficult for a user to identify the pieces of data that are of interest. By categorizing the broadcasting data in the control field of the header, the user's terminal can selectively display only those parts that are of interest to the user. The advantage of such a selective push scheme, as opposed to the non-selective scheme, is that the user is not required to know the actual Web site address of the broadcasting server; the terminal automatically selects the information of interest to the user. After the basic information is received and displayed on the user's terminal, the user can easily navigate to the corresponding Web site by clicking the appropriate links.

BROADCAST INDEXING FOR POWER SAVING AND PROCESSING LOAD REDUCTION

In the proposed scheme, the terminal must examine every datagram to identify those with information that might be required by the user. Such an operation could represent a significant overhead to the terminals in which the lack of processing power and battery capacity are crucial factors. If APs were to provide information in advance about the broadcasting data,[4] the terminals could then reject broadcasting frames of no interest without processing those frames at all at the MAC and the IP layers.

More specifically, the content would be broadcasted via a pre-determined MAC address, IP address, and port number. Thus, every MAC frame received from the AP with an address that the user does not want should be abandoned at the MAC layer of the terminal. It would save the processing power and the battery power at the

[3] *For example, when all the APs are in close geographical proximity.*

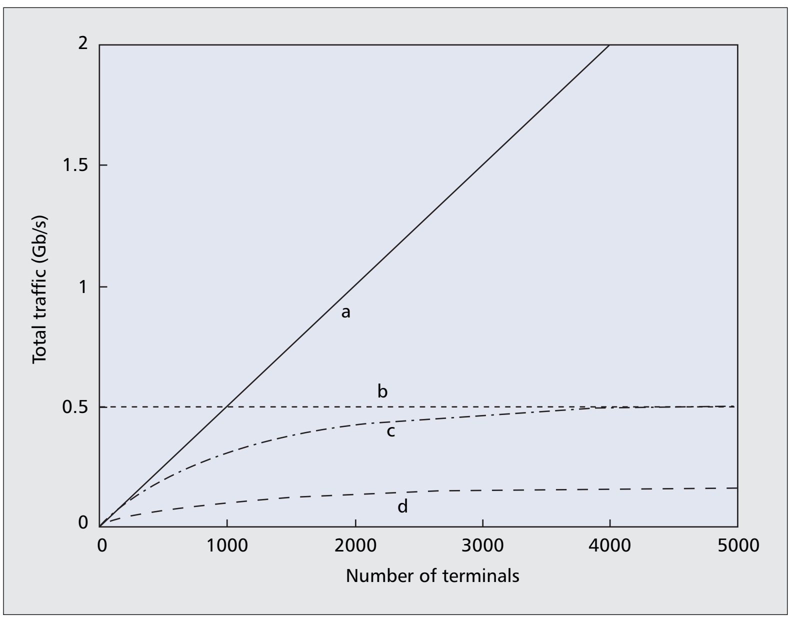
[4] *Such as the times at which the data will be broadcasted, the port number, or even particular IP/MAC addresses.*

broadcast_signal frame										
signal_header				broadcast_info						
				broadcast_current					broadcast_avail	
packet_class	repetition_period	BS_id	location_id	info_class	req_period	prog_id	MAC/IP/port addr	broadcast_period	the same to broadcast_current	urgent_info

broadcast data_frame					
data_header					payload_data
packet_class	req_req	prog_id	BS_id	location_id	

broadcast_req_frame	
subscriber_info	prog_id

■ **Figure 4.** *Examples of some main data formats.*



■ **Figure 5.** *The comparison of network traffic for the unicast method and variants of the proposed method: a) the unicasting method; b) the location-based IP broadcasting method (as in Fig. 1); c) location-based IP broadcasting with triggering (as in Fig. 2); d) location-based IP broadcasting with triggering and multicasting (as in Fig. 3).*

terminal, as compared with the case when the frame is abandoned at higher layers. For example, this selection operation also could be performed at the IP layer using an IP address, it is most efficiently performed as a lower layer operation.

Time indexing for the broadcasting method has already been proposed at the MAC protocol level to save power consumption [10]. In the same way, broadcast scheduling on an IP layer is possible. When a broadcasting server and an AP send broadcasting information to terminals, the information should contain the broadcasting times of each broadcasted contents. The terminals then know when the broadcasting data is going to be transmitted and can turn on the receiver at the indicated times. By using such a scheme, power consumption and processing load can be reduced significantly.

In Fig. 4, several kinds of data format are shown. The "broadcast_signal frame" is used for providing broadcasting information to terminals in a subnet, which consists of the information of the currently broadcasted data and the available broadcasted data. The "MAC/IP/UD/port address" field for each broadcasting data is shown. The "repetition_period" represents the time period for repetitively broadcasting the content; the "req_period" is a request for increase in the time-out period sent by terminals to APs; and the "broadcast_period" is the broadcasting time period for terminals used for power saving.

The "broadcast_data frame" is used to deliver broadcasting data to terminals within the "payload_data" field of the frame, where the "req_req" is the time left to terminate the broadcasting of the content. Finally, the "broadcast_req frame" is used by a terminal to request broadcasting data from its AP.

PERFORMANCE EVALUATION

Figure 5 shows the comparison of the network traffic between the existing method and a number of variants of the proposed method. The results were obtained by simulation for the case of a broadcasting server connected to the Internet and six thousand terminals that are uniformly distributed among one thousand APs. In addition, it is assumed that, on the average, three APs are connected to an edge router that supports Internet multicasting protocol. For the results to be general and independent of specific protocols and protocol settings, the details of the wireless communication protocols and Internet protocols are disregarded in the simulation. It is assumed that all the terminals are to receive the broadcasting data from the APs and that the broadcasting data rate is 500 kb/s, which should be included in the total data rate of the wireless LAN. As shown in Fig. 5, in the case of the unicast method (curve *a*), the total network traffic increases linearly with the number of terminals. In contrast, for the proposed location-based IP broadcasting technology (curve *b*), the total traffic is fixed, is independent of the number of terminals, and depends only on the number of APs. On the other hand, since the location-based IP broadcasting with triggering improves the utilization when there are only a few terminals in the radio zone, the curve *c* in Fig. 5 shows the significant reduction in network traffic when the number of terminals in the network is small. For the location based IP broadcasting with Internet multicasting and triggering (curve *d*), the network traffic is reduced to about one-third of the case when no Internet multicasting is used (curve *c*). This result stems from the fact that three APs are connected to a router, and an Internet multicasting datagram that is sent from a server is shared by the three APs. The technology used in curve *b* is mandatory; the others are optional according to a particular implementation.

EXAMPLES OF APPLICATIONS

The location based IP broadcasting technology can be used for providing location-specific information to users based on the position of their associated APs. The applications could be categorized as location-based services (LBS), private broadcasting services (PBS), and digital multimedia broadcasting services (DMBS).

- Examples of *location-based services* applications:
  - –Location-based geographic information services
  - –Location-based community news
  - –Location-based shopping information services
  - –Location-based tourist information services
  - –Emergency guide services
  - –Traffic information services

As a user moves into a radio zone, the user can receive location-specific information without the knowledge of the user's position information. This feature is very convenient for drivers and pedestrians with limited capability for handling Web searching. Furthermore, it ensures privacy of the user's location information.

- Examples of *private broadcasting services*:
  - –Announcement service in a sports stadium or a theater
  - –Conference services
  - –Emergency announcements

When many people gather in a place and need the same information, the location-based broadcasting can be a very efficient solution. In particular, WLANs with location-based IP broadcasting could be used to implement an unlicensed broadcasting system. For instance, an AP located at the center of stadium with omni-directional antenna, might be able to provide coverage for the whole stadium. One such application, emergency evacuation directions, could be implemented by a battery-operated AP unit with data storage. Such a system would work without the requirement of a network connection or power supply.

- Digital multimedia broadcasting services (DMBS)
  - –E-education services
  - –Indoor and outdoor DMB services

The proposed technology supports services much like the common broadcast radio or TV: a user can just turn on the receiver and select the preferred multimedia data.

CONCLUSIONS

The scheme proposed in this article can significantly reduce the network traffic and the server load and can eliminate the burden of the multicasting protocol, especially the signaling part, as well as of the IP address management by terminals and by service providers. The scheme provides radio-like broadcasting services to mobile users, who could turn on their terminal and tune to the desired content. The technology can be applied to all networks that use Internet protocols as their core communication protocols, and it is an appropriate solution for location-based service and telematics applications.

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BIOGRAPHIES

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