Chapter X
A Generic Framework for Bluetooth Promoted Multimedia on Demand (BlueProMoD)

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ABSTRACT
In recent years many technologies have converged to integrated solutions and one of the hottest topics has been the deployment of wireless personal area networks (WPANs). In this article we present a generic architecture scheme that allows voice and other real-time traffic to be carried over longer distances. The proposed scheme is a novel framework that combines a wired backbone network including Bluetooth access points (APs) with the mobile Bluetooth-enabled devices of the end users. This scheme is called Bluetooth Promoted Multimedia on Demand (BlueProMoD). BlueProMoD is a hybrid network and provides free-of-charge communication among customers, multimedia advertisements, as well as location-based and other value-added services.

INTRODUCTION
The concept of personal area network (PAN) is relatively new. A PAN, basically, is a network that supports the interoperability of devices in personal space (Elliott & Phillips, 2003). In this sense, it is a network solution that enhances our personal environment, either work or private, by networking a variety of personal and wearable devices within the space surrounding a person and providing the communication capabilities within that space and with the outside world (Prasad & Munoz, 2003). A wireless PAN (WPAN) is the natural evolution of this concept, where all participating devices communicate wirelessly. Furthermore, a WPAN is a network that moves with a person, linking all the devices carried by the person with each other, as well as any devices that are met along the way.
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Since a WPAN has by definition a limited range, compatible devices that are encountered along its path can either link to it or leave it when they go out of its range in a flexible and secure way.

The limited range of a WPAN offers additional advantages such as low-emitted power (thus reducing potential health risks), lower power consumption (hence longer battery life), and lower probability of interference from other WPANs as well as the possibility of location-based services (LBSs). Nevertheless, the core of a WPAN is the wireless technology employed. Nowadays there are many such technologies to choose from. Each one offers specific advantages and disadvantages, which should be taken into consideration before deciding on the most suitable for a particular service or environment.

Of all current wireless technologies Bluetooth is the most promising and employed for many real-life applications. Applications using Bluetooth have become important in hot spots such as at hotels, shopping malls, railway stations, airports, and so forth. Bluetooth is a well-established communications standard for short distance wireless connections. A wide range of peripherals such as printers, personal computers, keyboards, mouse, fax machines, and any other digital device can be part of a Bluetooth network.

Bluetooth has many advantages: (1) low cost, (2) considerable degree of interference-free operation, (3) speed, (4) appropriate range, (5) low power, (6) connectivity, (7) provision for both synchronous and asynchronous links, and (8) wide availability in mobile phones, PDAs, and other devices. Bluetooth is usage-scenario driven, in the sense that its design points were optimized to satisfy established market needs (Bisdikian, 2005). Such usage scenarios are headset to mobile phone connectivity (hands free); mobile device to computer synchronization; digital camera to printer connection for printing; and so forth. More sophisticated applications in diverse areas have been investigated such as hotel services (electronic door locks, check-in/out) in Starwood Hotels and portable patient monitoring in hospitals so that recovering patients are not confined to their rooms (Dursch, Yen, & Shih, 2004). Another interesting application of Bluetooth technology took place at the CeBIT 2001: Guiding services for finding the shortest path to a particular exhibitor in the hall as well as additional exhibitor information services were implemented (Kraemer & Schwander, 2003).

The core of Bluetooth technology is based on the IEEE 802.11 standard and it is a wireless system for short-range communication. This standard defines the protocol for two types of networks; client/server and ad-hoc networks. Bluetooth supports both point-to-point and point-to-multipoint connections. Both Bluetooth and most of IEEE 802.11x share the same 2.4 GHz industrial, scientific and medical, license-free frequency band. Compared with other systems operating in the same frequency band, the Bluetooth radio typically hops faster and uses shorter packets.

In this article we propose a generic architecture scheme that allows voice and other real-time traffic to be carried over longer distances, while simultaneously showing how the providing organization can experience sufficient revenues in order to finance and maintain the necessary infrastructure. The proposed scheme is a novel framework that combines a wired backbone network including Bluetooth access points (APs) with the mobile Bluetooth-enabled devices of the users. The end result is a hybrid network offering free voice and other communication in return for short, specifically targeted multimedia advertisements and tracking information on behalf of the stores or branches operating at a large shopping center or complex. Location-based and other services are also envisaged as a natural side effect. An additional advantage is that the user perceives such capabilities as part of the services offered by his/her respective WPAN.

This article is structured as follows. In the following section we give a detailed overview of the most important technical characteristics of
Bluetooth, such as hardware, connectivity, security, error control, interference, and health issues. The proposed generic framework (BlueProMoD) is described next, where we present all the critical components. Finally, conclusions together with future work are presented.

**BLUETOOTH DESCRIPTION**

In this section we briefly discuss some important characteristics for the Bluetooth technology. The basic form of a Bluetooth network is the piconet. This is a network with a star topology with up to eight nodes participating in a master/slave arrangement (one master and up to seven slaves, see Figure 1a). More specifically, the master is at the center and transmits to the slaves; a slave can only transmit to the master, provided it has been given prior permission by the master. This protocol allows both asynchronous and isochronous services to be realized. The communications channel is defined by a pseudorandom sequence of frequency hops over 79 frequency sub-bands 1 MHz wide, in the 2.4 GHz band, ranging 2.402 - 2.480 GHz. There are three main Bluetooth versions according to the transmission rate (see Table 1).

There are also three classes of antenna power emission and thus possible ranges, namely Class 1 (100 mW, 100 meters), Class 2 (2.5 mW, 10 meters), and Class 3 (1 mW, 1 meter). Typical mobile phones operate at Class 2. Due to the extremely low power emission, investigators agree that Bluetooth products have not been identified as posing any health risks (Erasala & Yen, 2002). Table 2 presents all the possible modes of a device using Bluetooth technology.

A piconet is created in two stages, the first of which is optional: In the first stage, a device inquires for other devices in its vicinity; if a device responds to the inquiry message it transmits its own Bluetooth address among other information. A Bluetooth address is a unique 48-bit integer derived by the manufacturers from the same address space and authority as the IEEE 802 MAC addresses.

In the second stage, a device (the master) that wants to communicate with another device must perform paging. The paged device (the slave) responds by notifying the paging device that it is ready to communicate with it. In this case the paging device assigns a so-called active member

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**Table 1. The main Bluetooth versions**

<table>
<thead>
<tr>
<th>Transmission rate (gross)</th>
<th>Bluetooth version</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Mbps</td>
<td>1.0/1.1/1.2</td>
</tr>
<tr>
<td>3 Mbps</td>
<td>2.0/2.1 (+ EDR)</td>
</tr>
<tr>
<td>480 Mbps</td>
<td>“Seattle” (draft status)</td>
</tr>
</tbody>
</table>

**Table 2. Possible modes of a device under Bluetooth**

<table>
<thead>
<tr>
<th>Mode</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STANDBY</td>
<td>The device is not connected in a piconet; it listens for messages every 1.28 seconds over 32 hop frequencies.</td>
</tr>
<tr>
<td>PAGE/INQUIRY</td>
<td>The master sends 16 identical page messages to the slave in 16 hop frequencies, repeating this process if there is no response from the slave.</td>
</tr>
<tr>
<td>ACTIVE</td>
<td>This represents the actual data transmission.</td>
</tr>
<tr>
<td>HOLD</td>
<td>The device conserves power by not transmitting any data.</td>
</tr>
<tr>
<td>SNIFF</td>
<td>The slave does not take any active role in the piconet, but only listens at a reduced power consumption level; though this level is higher than Hold.</td>
</tr>
<tr>
<td>PARK</td>
<td>The slave is synchronized to the piconet, but is not part of the normal traffic.</td>
</tr>
</tbody>
</table>
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Figure 1. Examples of a Bluetooth: (a) piconet, (b) scatternet

address to the paged device. This is a relative address, which is only of local significance.

In a sense, the limit of seven slave nodes per piconet can be overcome whenever an eighth active node appears: The master takes a node and places it in “park” mode. In this state, the particular node relinquishes its active member address which is given to the newcomer. This feature allows up to 256 nodes to participate in a piconet, but only up to seven slaves to actively exchange data with the master at a time. Communication links may be of two types: synchronous connection-oriented (SCO) and asynchronous connectionless (ACL). SCO links are typically used for voice communication, whereas ACL links for data. The former are strictly real time, hence lost or damaged packets are never retransmitted over SCO links.

Bluetooth scatternets can also be formed by the connection of two or more piconets. In this case they can have entirely or partially overlapping frequencies, apart from the ongoing communication with their respective members. Evidently one or more nodes must assume the role of a bridge between adjacent piconets (see Figure 1b). As expected, a bridge node operates using the store-and-forward paradigm in order to forward a packet from one piconet to an adjacent one. It is possible for a bridge node to be the master in one of the piconets, but in general this is a slave node. Communication is first initiated by the master of the first piconet, which sends a packet to the bridge node where it is stored; whenever the master of the second piconet allows it the bridge node sends the stored packet to the master. Given that the two piconets are not coordinated in any way (in effect the two masters), the overall waiting time at the bridge node during switch over can be quite long. The Bluetooth specification switch-over does not define any particular mechanism, protocol, or algorithm in order to guarantee some minimum time for multi-hop communication in scatternets.

In order to ensure that different hardware implementations are compatible, Bluetooth devices use the host controller interface (HCI) as a common interface between the host and the core. Logical link control and adaptation protocol (L2CAP) is built on top of HCI, which basically segments and reassembles large data packets over Bluetooth baseband connections. Higher level protocols such as service discovery protocol (SDP), RFCOMM (serial port emulation), and telephony control protocol (TCS) are built over L2CAP. Applications are built over them.
using the services provided. To give the reader some rough background about other aspects of the Bluetooth communication, such as security, interference, and real-time traffic, we present them briefly next.

**Security**

A challenge-response mechanism is employed for authentication using Bluetooth address as the public key and a 128-bit integer during device initialization as the private key. In addition, another 128-bit random number is used for each new session. Encryption is also included to maintain link privacy. As a result, devices can be classified as “trusted” and “untrusted,” and services as “requiring authorization and authentication,” “requiring authentication only,” and services open to all devices.

In order to reduce security risks, as well as accelerate device discovery, it has recently been proposed to use limited duration visual tags provided by a central trusted authority for specific devices, so that users can quickly identify the one of interest among many available and connect to it (Scott, Sharp, Madhavapeddy, & Upton, 2005). Nevertheless, security problems have been identified with Bluetooth. In a recent article (Shaked & Wool, 2005) an implementation of a passive attack is described under which a 4-bit PIN can be cracked in less than 0.3 seconds on a Pentium III 450 MHz computer.

**Interference**

Frequency hopping and the short range of a piconet are the deciding factors for experiencing minimal interference problems under Bluetooth. This minimizes interference not only among Bluetooth devices or piconets, but also interference from other types of devices such as microwave ovens, mobile phones, and baby monitors.

The case of coexistence of Bluetooth with wireless LANs in particular has been studied extensively due to the popularity of IEEE 802.11x devices, which happen to use the same frequency band. Nallanathan, Feng, and Garg (2006) present a complete integrated analysis taking various scenarios into consideration. A Bluetooth piconet in a multi-piconet environment is first examined.

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**Figure 2. Example of 3-slot packet from a slave after a 1-slot packet from the master**

![Diagram of 3-slot packet from a slave after a 1-slot packet from the master]
for all three types of packets (that is, 1-, 3-, and 5-slot packets), concluding that 1-slot packets are the best for high density interference, 3-slot packets for moderate, and 5-slot packets for low density interference (see Figure 2). In the mixed environment of Bluetooth and IEEE 802.11b, the latter suffers more from interfering Bluetooth devices than the other way around; in fact IEEE 802.11b successful reception packet rate increases when Bluetooth uses 5-slot packets.

Real-Time Traffic over Bluetooth

Real-time traffic is of particular importance in present-day networks, since it constitutes a significant proportion of user sessions—especially voice due to its limited bandwidth requirements. As noted earlier, Bluetooth supports voice traffic over SCO links by design, using constant bit rate (CBR) at 64 kbps per channel. In order to support this rate and the expected quality of service, a strict timing scheme has to be observed, which may lead to severe deterioration of the asynchronous links performance. Furthermore, only up to three SCO links are supported per piconet.

Given these limitations it is not surprising that researchers tried to calculate the actual SCO link performance. The next step was to use the similar experience from voice-over-IP (VoIP) in order to explore the possibility of using ACL links for voice traffic. In Misic, Misil, and Chan (2005) a detailed analysis is presented under which the presence of a single SCO link reduces the bandwidth available to ACL links to two thirds of the original; with two SCO links, the ACL bandwidth is reduced to half of the original; and with three SCO links the ACL bandwidth is practically zero. The authors evaluated their scheme, which uses multi-slot ACL packets to carry CBR voice traffic, concluding that it is more efficient.

Zeadally and Kumar (2005) used the audio/video distribution transport protocol (AVDTP) specification standard. The results showed that even AVDTP itself can offer 48.2% performance improvement when the optimized version is used over the default version. A more recent study (Razavi, Fleury, Jammeh, & Ghanbari, 2006) considered MPEG-2 (video) traffic coming from an IP network to a Bluetooth master of version 2.0, supporting 2-3 Mbps. Their simulation results lead to similar conclusions. It is, therefore, clear that no complete scheme exists that is able to support simultaneous voice traffic for maximum size piconets (that is, all seven slaves carrying voice traffic) over ACL links. Such a scheme would greatly enhance the usefulness of Bluetooth, especially in view of the fact of the high gross data rates of version 2.0 and possibilities of interconnectivity with IP backbone networks.

DESCRIPTION OF THE BlueProMoD GENERIC FRAMEWORK

In this article a framework for the deployment of a novel usage model is presented. The proposed model offers users free of charge voice, location-based, and other services in return for specifically targeted short advertisements on their mobile devices, based on a Bluetooth hybrid network. The whole network environment is run by a single managing authority typically in a large shopping mall or organization (for example, a university campus with short distances between buildings). Revenues to support the system functionality come from the advertisements of participating resellers as well as value-added services, such as the one coming from the post processing of users movement tracking.

The BlueProMoD generic platform requires four types of hardware communicating entities: (1) the server(s), (2) the Bluetooth APs, (3) the interconnection network between the APs and the server, and (4) the Bluetooth-enabled user devices. In its basic form, the user first downloads the client application from specific APs at the reception area. The client application distinguishes BlueProMoD APs from all possible surrounding
Bluetooth devices and selects one of them for connection, typically the one with the strongest signal, after proper registration or authentication. From this time onwards the user is able to use all free services offered by the system. The mandatory services provided by all variations of BlueProMoD are: User Reception, SMS, and MMS over Bluetooth, Voice over Bluetooth, Users’ Directory, and User’s Location. The latter is the foundation upon which LBSs may be built, among which route finding and m-advertisements from shops are the most important. The User Reception service is obviously essential since it allows a user to connect to the system.

BlueProMoD is a three-tier architecture, an overall description of which is shown in Figure 3. These are the Client, the Core Server, and the External Services tier.

**Client Tier**

The client tier is composed of a Bluetooth-capable cell phone or PDA running the appropriate client application, which allows the user to connect to any available Bluetooth AP, offering the Reception Service. The client application is downloaded and installed only at specific reception areas. For this reason first-time users can seek assistance from experienced personnel (for example, at the help desk or information points). At the same time, this arrangement places fewer burdens on the overall system since long or unsuccessful loading efforts are limited to areas that do not need to constantly interact with the rest of the system. The whole process mentioned previously is more secure and reduces user frustration from unsuccessful or long loading times.

After registration and authentication, the user is presented with a list of available services. This step is important since it is the only way that the system can ask personal information from the user and identify him/her every time he/she returns for another visit. Since Bluetooth devices are widespread it is quite natural that many such devices may exist in the same area apart from client devices and Bluetooth APs. In order to improve user satisfaction and reduce client connection time, the client application automatically stores user identification information on his/her device that is made directly or indirectly available (for
example, via a signed ticket for higher security) upon request from a Bluetooth AP.

The client application searches for Bluetooth devices offering the Reception Service (hence with a specific UUID). To reduce overall system workload even further, apart from user information, the client application sends a specific ID which indicates to the Bluetooth AP that the sender is a client application. In this way, only clients can connect to Bluetooth APs and only Bluetooth APs can connect to clients.

Typically there are at least four types of clients: (1) administrator, (2) employee, (3) retailer, and (4) other. The first class is reserved for the system administrators and the second for privileged users who must have more rights than other users (for example, unlimited talking time and no advertisements); retailers who may pay for the system are assigned to the third class with almost the same rights as the second class; ordinary users obviously belong to the final class. There are three basic states at which a user may appear in the system. These states are Ready, Busy, and Disconnected (see Figure 4).

The first state is entered after the user connects to the system; the user remains in this state throughout the connection with the exception of the Busy state. The Busy state is entered when the user is in the middle of a phone call. The last state represents a user who has logged out or disconnected from the system for a specific timeout period. These states are also necessary for the Users’ Directory service to be up-to-date. In this way system resources are not wasted unnecessarily (for example, if a user A knows that user B is busy talking, he/she will not try to call him/her for a while unless it is really urgent).

Connection time can be further improved once a client device has connected once and remained in the vicinity of the same Bluetooth AP. The Bluetooth standard allows up to 255 devices to remain in the PARK mode, waiting to “wake up” and become one of the seven slave nodes that are actively communicating with the master. In our case, this implies that the device discovery time can be eliminated in subsequent communication sessions between the user and the particular Bluetooth AP.

Core Server Tier

The core server tier is composed of the processes involved in order to provide the basic services of BlueProMoD. These processes are: User Reception; short message service (SMS) and multimedia message service (MMS) over Bluetooth; voice over Bluetooth; users’ Directory; and user’s location. Upon running, the client application first determines the appropriate Bluetooth AP to be connected with. After a network connection is es-

Figure 4. The three basic states of a user
tablished with the system for the first time, the user is asked several questions in order to be registered with the system. After this is completed, the user logs in to the system and his/her account is updated, reflecting his/her voice credits, IP address, position, and so forth. All these separate actions are performed by the User Reception as the main service that interacts with the Users’ Directory and User’s Location services. From then onwards, the User Reception service is chiefly responsible for periodically checking whether a user is still connected to the system, since it is possible that he/she disconnects in an abrupt way.

The rest of the services run as processes that mostly sit, passively waiting for an event either from a user (for example calling or being called) or from the external services tier (an advertisement generated by a retailer). Since these services require at least a BlueProMoD server, the Bluetooth APs, and the interconnection network, it is important to turn our attention to these components and their interaction.

**Bluetooth APs Placement**

Bluetooth APs must be appropriately placed so that there is a complete coverage of the targeted area. In order to reduce unnecessary load as well as annoyance to the users, the APs only recognize and generate connections with client devices that run the particular client application; other Bluetooth devices (for example hands free) as well as other Bluetooth APs cannot interfere since they have a different than expected service ID. This arrangement, however, covers only one of the considerations during the deployment of the APs.

The Bluetooth APs must cover all areas traversed by potential users. Since Class 2 devices have a typical range of 10 meters one could assume that placing APs at approximately 20 meters apart would solve the coverage problem. Unfortunately this is not that simple. If there are many obstacles that absorb part of the signal, more APs are needed, placed at a high point in relation to these obstacles (for example top of shelves). Large areas with no columns in the middle also cause a problem, typically solved by placing APs on the ceiling. Nevertheless the effective range of the particular APs is now reduced. For ceilings that have a height approximately equal or larger than the typical AP range of 10 meters, the straightforward solution is to create appropriate booths at the floor for the APs to be housed, although it is not always possible to do so.

Another consideration in placing Bluetooth APs is the coverage of congested areas. By “congested” we mean areas where there are likely to be more than seven users that want to use the voice service simultaneously. Typically, this is the reception area as well as coffee shops and any other area where users can sit and relax. A Bluetooth AP without obstacles can cover an area of $\pi R^2 \sim 300 \text{ m}^2$, where only up to seven clients can be active in the respective piconet. Such an area could have as many as 100 users who may wish to place or receive voice calls simultaneously in the worst case. Although they can all be accommodated in the PARK mode, they cannot be active in the same piconet. Obviously all such areas require more Bluetooth APs so that the waiting time for the voice service can be minimized. Other considerations may also prove important, such ease of service and replacement for defective APs, security, and cost.

**Interconnection Network**

In terms of network infrastructure BlueProMoD requires at minimum a WPAN for each user and Bluetooth AP, as well as a backbone network. Although an IP-wired network can be used for this purpose, different packetization schemes and other problems could tempt designers to opt for a scatternet-based backbone. Considerable research effort has been placed on the development of scatternet and routing schemes to this end. Pabuwal, Jain, and Jain (2003) have developed a complete
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architectural framework, implementing among others several ad-hoc routing protocols, such as destination sequence distance vector (DSDV), clusterhead switch routing (CGSR), and cluster based routing protocol (CBRP). Although the authors report that they built a complete multimedia application to run over it, no details are given about its performance under different scenarios.

The work in Duggirala, Ashok, and Agrawal (2003) provides a more detailed scheme called BEAM, under which Bluetooth bridges can effectively negotiate their participation in neighboring piconets. They report that slave piconet nodes are better for the bridge role, as well as that such nodes should be assumed as carrying additional traffic apart from the transit one between neighboring piconets. Although their proposal is interesting it requires Bluetooth manufacturers to incorporate their framework in their products. However, the most important result for our discussion is that bridge nodes can delay traffic significantly since they are slaves and need to use store-and-forward by default.

For this reason as well as the complexity in the formation and routing in scatternets, and security reasons described earlier, we believe that IP-wired networks are better candidates for backbone networks. In addition, such networks offer much higher, interference-free bandwidth at a smaller cost, as well as easier software development, since programming for communicating IP nodes using the sockets API is a de facto standard. The Bluetooth APs must support the PAN profile (the LAN profile is deprecated in Bluetooth v2.0). Typically, L2PCAP is used to establish an ACL connection between a Bluetooth AP and a client device. IP data transfers are facilitated using two possible methods. Under the first (and older) method, IP runs over PPP, which, in turn, runs over RFCOMM. Under the second method, IP runs over BNEP, which offers a layer-2 protocol type similar to Ethernet. Newer and more expensive cell phones support the PAN profile, whereas cheaper and older cell phones support the former method.

In all cases, a Bluetooth AP essentially plays the role of a bridging network device between the two different network technologies.

In terms of device connectivity, there are at least two possible paths. Under the first, each Bluetooth AP is an intelligent device, which can directly translate between Bluetooth and IP. In this sense, it can be a dedicated device or a USB dongle connected to a small computer. Unfortunately, the USB standard specifies that the maximum distance from a computer to a full-speed device is 5 USB hubs (at 5 meters each) and an additional 5-meters cable, yielding a total of 30 meters. Obviously, such an arrangement is appropriate only for congested areas in the best case. Vendors, however, have come up with various cost-effective solutions that address this limitation. Some sell USB extenders, which can run reliably at distances of up to 50 meters from the attached computer. Others propose a hybrid approach where Ethernet cables are used to connect suitable USB hubs at 12 Mbps per port; up to five such hubs may be connected to a single computer in a transparent way for existing applications. Such a computer would obviously have to host a proxy ARP, router and—preferably—DHCP servers (depending upon the client connection type/profile) and would connect with the BlueProMoD server. Yet another proposal essentially incorporates a miniature computer at the end of an Ethernet cable with a Bluetooth interface on the other end. In all cases, there are several ways to address the problem of interfacing the Bluetooth APs to the backbone.

The Server

The server is responsible for all of the basic available services as well as other administrative work such as client activity logging and connection to external services. The primary service offered is the reception service which works closely with the users’ directory and location services. Client activity logging is also performed on this server,
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with the relevant data periodically transferred to the External Services tier, so that only recent activity is maintained; older activity is moved out for post processing (for example marketing research). Since BlueProMoD is intended for large organizations, at least two more issues are involved: scalability and reliability.

The server must be able to connect and support all Bluetooth APs. Each Bluetooth AP should not only support its piconet of up to seven active nodes, but also all of the nodes in PARK mode. All these possible user connections are dynamic in nature and could overflow a central DHCP server. Hence, a DHCP server must exist either at each Bluetooth AP, or more preferably on a pool of Bluetooth APs covering neighboring areas. Such a hierarchy reduces the DHCP server load, avoids the single point of failure, and facilitates user roaming as discussed later.

The second issue regarding the BlueProMoD server is reliability of service. Since user authorization/authentication and activity logging takes place at this server, a back-up BlueProMoD server is required. In order for the server transition to take place gracefully, the back-up server must be kept at strict synchronization with the primary. At the same time, for security reasons, no other node can communicate directly with it when the primary server operates normally.

Location-Based Services

LBSs are an emerging technology in wireless telecommunications. One of the most powerful ways to personalize mobile services is based on location. Mobile nodes or even PANs can be combined with a suitable backbone network in order to determine their location and advertise their presence in the overall system. This basic capability has led to the development of numerous services, such as service route finder; access to catalogue data, area guide, and advertisement of goods offered by local retailers; tracking of vehicles and people; or even mobile gaming (Hand, Cardiff, Magee, & Doody, 2006). Some of them are very essential and will be offered by the BlueProMoD.

However, for such services to be effective, the location of the mobile node must be adequately fine grained. For example, an accuracy of 100 meters for route finding in a national highway may be adequate, but is unacceptable in a commercial mall environment. By design, Bluetooth has a typical range of 10 meters (Class 2). However, Bluetooth signal strength is adaptable in the effort to conserve power consumption; a node tries to reduce its signal strength to the minimum required for communication with its peers. Hence, the location accuracy can be further improved if Bluetooth signal strength measurements are taken into account (Peddemors, Lankhorst, & De Heer, 2003). Nevertheless, there are two inherent Bluetooth characteristics that must be taken into account: First, the link quality is relative since it is measured in a manufacturer-specific way. Second, Bluetooth device discovery is typically performed at regular intervals of 20 seconds; this can be a problem in the case of a fast moving node. In the case of a pedestrian walking in a large building complex such as a shopping center, hotel, hospital, or university, however, the previous characteristics do not represent a major problem.

External Services Tier

This is composed of one or more servers, external to the basic BlueProMoD, offering all the non-basic services of BlueProMoD, as well as a DBMS for the advertisements, accounting and Internet services. For example, under a certain variant of BlueProMoD it is possible for some clients to be offered VoIP over Bluetooth, in order to call any telephone outside the area supported directly by BlueProMoD. Nevertheless, the advertisements (announcements in the case of universities or other nonprofit organizations) through targeted MMSs and LBS such as route finding remain some of the most important services, since they represent a
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significant portion of the system revenues. These should be sent sparingly to the appropriate target user groups to have maximum effect. For example, sending an advertisement for children shoes to a single man is different from advertising a popular children’s toy to a mother in her early 30s just before Christmas.

Apart from the marketing issues, which are outside the scope of this article, there are several technical issues involved that belong in this tier. Free voice calls and MMS are expected to be the main attraction of the system, apart from route or goods finding. Instead of creating multiple versions of Web pages to be displayed on various device classes (for example, cell phones, PDAs, portables, info-kiosks, etc.), the content creator could follow certain guidelines to prepare a single version; upon request, the particular Web page could then be sent to a gateway, which would translate it to the appropriate format before sending it to the requesting user. This gateway also plays the role of a buffer between the core server and external services tier (see Figure 3).

**Handover**

An important part of the system functionality is the handover mechanism, when a client moves from one Bluetooth AP to another. When a user uses his/her cell phone for voice communication, he/she is used to speaking while moving at a normal walking speed; hence, he/she expects to receive an unbroken voice communication service. One of the major limitations of the Bluetooth standard is that it does not provide any mechanism for managing micro-mobility. In Kraemer and Schwander (2003), the inquiry procedure for the determination of the locations of user mobile devices and the connection to the nearest AP was measured to be up to 5 seconds. Furthermore, it is possible for a user that remains stationary to lose his/her connection to the respective Bluetooth AP for a short period of time. What happens when the user tries to reconnect? If he/she is in the middle of a voice call, reconnects, and his/her device assumes a different IP it appears as if the user lost the previous session.

The solution to the latter problem is relatively straightforward taking into account a particular feature of DHCP. More specifically, a client that has recently acquired an IP address can reconnect asking to be assigned the same IP address. If this IP address has not been assigned to anyone else, it is possible for the DHCP server to grant such a request. In our case, let us assume that the IP address space is large enough and each new connection is granted one of the not recently used IP addresses; there is a good chance then that a recently disconnected client will be granted the old IP address. This approach works well and places minimum burden on the network and the DHCP server. Furthermore, users in PARK mode at the same Bluetooth AP appear connected constantly with the same IP address initially assigned to them.

Such an approach also works for roaming users if a DHCP server is responsible for a pool of neighboring Bluetooth APs. Such users typically walk at a slow pace when they talk and tend to remain in the same general area. Hence, the only disruption will be short and depend almost entirely on the adopted Bluetooth hand-off mechanism. In this way more complex forms of addressing the roaming user problem (for example mobile IP) are avoided. Voice over Bluetooth is the only form of user communication requiring special consideration; all other forms of communication are nothing but a series of short TCP/UDP transactions not significantly affected by any change in the IP address of communicating parties. Finally, communications among users is only allowed on a user-to-user basis, so that malicious users cannot easily overload the system.
A Generic Framework for Bluetooth Promoted Multimedia on Demand (BlueProMoD)

CONCLUSION

Bluetooth consists of the most promising and well-established wireless technology for a vast number of applications. In this article we have presented a generic framework, called BlueProMoD, based on Bluetooth technology. The main aim of the proposed framework is to support large commercial enterprises (or organizations) at the retail level. BlueProMoD uses all the advantages of Bluetooth in order to provide free-of-charge communication and other services to simple users in return for limited and centrally controlled advertisements from the local retailers, who will have to pay for the system (hence promote it). However, user activity logging is envisaged as the main source of revenue, since valuable marketing information may be extracted from it. The advantages of deploying and supporting the BlueProMoD-based system are straightforward, which combined with its cost effectiveness make it an important tool in such environments.

A future work is to build a prototype as well as conduct extensive simulations in order to determine specific costs and technical profiles that will demonstrate these advantages quantitatively.

REFERENCES


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