Abstract—The IEEE 802.11 family of WirelessLAN enable broadband wireless access at low cost but has limited distance range. The 3G Wireless network enable wireless data access over much longer distance of cellular sites and with the handover and roaming can be used globally. Yet the 3G Wireless may be more expensive. The WirelessLAN and 3G Wireless have different capabilities in distance range, data rate, and in other features, and may complement each other. Combining WLAN and 3G Wireless data through interworking will enable these LAN and WAN technologies to complement each other to enhance the available wireless network services. These benefits are of value to both users and service providers. The requirements of interworking and the technological implications of these requirements are discussed here.

Index Terms—WirelessLAN, Interwork, 3G Wireless.

I. INTRODUCTION

As the usage of data has been growing rapidly, the growth in wireless follows. Wireless data networks enable users to access data network and to do so with the convenience of mobility. Yet many different network systems have been deployed to serve different customers and for different purposes.

Among the very popular ones are the IEEE 802.11 family of WirelessLAN (WLAN) and the family of PLMN Wireless Data Networks, which are originally serving different customer needs. They have both become popular and their customer bases have both overlaps and differences. They are quite different in technology but interworking these network systems will enable better service to the customers.

The PLMN Wireless Data Networks include 2.5G/3G/3.5G Wireless data networks, but we use 3G Wireless only for the discussion here. 3G Wireless alone is a family of different PLMN standards, including UMTS and CDMA2000. The interworking between WLAN and CDMA2000 was discussed in [1]. We discuss the general requirements and possible technologies of interworking here. A more basic meaning of interworking may also be found elsewhere such as in [2].

The comparison of the features between WLAN and 3G Wireless are summarized in Table 1.

Table 1: Comparison between 3G Wireless and WLAN.
III. BENEFITS OF INTERWORKING

Although 3G Wireless networks have a longer range as WAN, the data rate is lower. Although the 802.11 family of WLAN networks offers much higher data rates, it can cover only smaller areas.

Notice that the customers are primarily service users and it is undesirable if they had to subscribe to different types of network service providers to do what they want. Ideally, customers need to subscribe to one wireless service provider. It will then be the challenge of the service provider to provide complete wireless solution to the customers in order to increase customer satisfaction and to attract customers.

The above comparison of the two technologies shows that they possess many desirable and complementary features. Combining these two technologies will address the need for a total wireless solution for both WLAN and 3G Wireless.

Interworking means enabling WLAN users to seamlessly use 3G Wireless network will provide WLAN users with always-on and ubiquitous connectivity with below 2 Mbps data rates. Conversely, interworking also means enabling 3G Wireless users to seamlessly use WLAN (802.11) will provide 3G Wireless users lower-cost and higher data rate whenever the users is within the range of the WLAN networks. The performance and flexibility of wireless data services would be dramatically improved if users could seamlessly roam across the two networks.

Given the seamless connectivity between the local area network and mobile network, the interworking between WLAN-3G Wireless offers a wide range of coverage to the users. It also provides great opportunity to Mobile operators and WLAN service providers to make available various services such as accessing Internet and evolve their business profitably.

The business drivers for interworking are strong. Today, wireless telephony Service Providers are trying to gain market share, market penetration, and of course revenue growth by creating interfaces that integrate short range WLAN technology with various 3G technologies.

On the other hand, WLANs have gaining popularity and acceptance as more and more corporations implement local, wireless networks. WLANs are also popping up as “hotspots” in hotel chains, restaurants (Starbucks), etc.

Basically, what WLANs provide are wireless IP services in a small area. At the same time, service providers are using an IP backbone for various mobile phone services. What one may intend to achieve is an “always on” IP service availability independent of location, movement, or infrastructure. Interworking between WLANs and 3G Wireless will enable one to satisfy today’s driving need for wireless IP service.

IV. REQUIREMENTS OF INTERWORKING

Interworking different network systems involves internetworking, interoperability, mobility, and portability. We discuss these requirements here.

A. Internetworking requirements in terms of interfacing at different network protocol layers

Requirements to interfacing different networks may be expressed in terms of the 5-layered network protocol (physical, data link, network, transport, application) model.

The interface for internetworking may be at the link layer. An example of such an interface is the network interface between a frame relay network and an ATM network.

The interface may be at the network (IP) layer. Because the IP protocol is already used everywhere, it has become the standard protocol for network applications.

The interface may be at the transport layer, which may be using TCP or UDP depending usually on whether reliable transport or real-time transport is a more important requirement.

Although a standard protocol is used to interface between different systems, different applications in remote locations may also need to be interoperable.

Internetworking is usually pictured as shown in Figure 1.

![Figure 1. Network systems A and B interface with each other at the kth layer (represented by the dashed line) through intermediate gateways that translate the protocols.]

B. Interoperability
Remote users may be using running their applications on different operating systems, such as Linux, MS Windows, or Macintosh. These operating systems may also be running on top of different platforms, which may in turn be running on top of the different networks. Each of these platforms needs to have the appropriate application program interface. The applications are using higher level computer languages but the application program interface takes care of the translation for different platforms.

Different platforms may support different computing languages or different versions of these languages. It is desirable to standardize the user messages. A popular standardization is to use text-based user messages. Well-known examples are the web-browser and text-based e-mails messages. An example in wireless applications is text-messaging which can be exchanged between a cellular phone and a personal data assistant (PDA).

Internetworking is usually pictured as shown in Figure 2.

![Figure 2](image)

Figure 2. Application may execute in different systems A and B using different networks through the use of application program interface.

The above requirements to interface at the protocol layers are needed but do not sufficiently address the needs of interworking between different wireless networks.

C. Requirements in terms of user planes and control planes

Internetworking connects different networks through appropriate interfaces. The minimal requirement of the interface is to enable data sent from any user of one network A to cross from network A to another network B. These networks may be of different types. After crossing to the different network B, the user data may then be destined to a user in network B or may route via network B to another network C. In other words, the user planes of the different networks are connected.

In addition to enabling user data to route across different network, one may further require interfacing of the control planes of the different networks. For example, the signaling functions in the originating network may pass on through the transit networks to the destination network.

The destination network and the originating network may be of different types. Here the control functions need at least to route through the transit network to a destination network of the same type as the originating network. In addition, the controls may continue to function in the originating, transit, and destination networks even though they may be of different types. These control functions may not match exactly between different networks, so that the closest matches may be made. Enabling control plane messages to function across different networks can in turn enable various functions such as QoS capabilities and network management functions to be offered across different networks.

Again the above requirements are necessary and not sufficient for interworking between different wireless networks.

D. Requirements from the user perspectives and their technological implications

A system uses network but has to provide a set of complete solutions to the customer. Therefore, as we may also mentioned above, internetworking alone are not enough requirements for interworking two different wireless systems.

Different wireless network systems provide different network resources to customers. Interworking the different systems provide more services to the customers.

In the following, customer A to refer to a customer of a service provider in network A. Device A is a device supported by the service provider in network A. Application A is an application originally supported by the service provider in network A running on device A. Device B and application B have similar meaning. A general mobility requirement can be states as follows:

Customer A may run an application A or B, using device A or B, in network A or B to communicate with applications in other wireless systems in the same or different network.

This is a very comprehensive requirement, which we can subdivide into different mobility requirements.

1) Customer A may run an application A using device A in network A to communicate with applications in other wireless systems in the same or different network. This involves internetworking and interoperability requirements.

2) Customer B may run an application A using device A in network A to communicate with applications in other wireless systems in the same or different network. This involves personal mobility and security in addition to the requirements in 1).

3) Customer B may run an application B using device A in network A to communicate with applications in other wireless systems in the same or different network. This involves service mobility in addition to the requirements in 2).

4) Customer B may run an application B using device B in network A to communicate with applications in other wireless systems in the same or different network. This involves terminal mobility in addition to the requirements in 3).

A systematic way to organize these requirements is given in Table 2.

In 1), the interoperability requirements between different networks include the ability to tailor the application according to the services available.

An example is that a Toll voice application may be communicating to hi-fi grade sound application in a network with broader bandwidth not available to the network with the Toll voice application. If real-time communication is needed, the hi-fi grade sound may be downgraded to Toll
grade voice.

Table 2. Different types of internetworking, interoperability, and mobility requirements.

<table>
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<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<tbody>
<tr>
<td>Customer</td>
<td>A</td>
<td>B</td>
<td>B</td>
<td>B</td>
</tr>
<tr>
<td>Application</td>
<td>A</td>
<td>A</td>
<td>B</td>
<td>B</td>
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<tr>
<td>Device</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>B</td>
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<td>Network</td>
<td>A</td>
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</table>

Another example is to run a client application from the slower bandwidth network with a server application from a broader bandwidth network. For example, a system A application supports streaming to a slower bandwidth because of lower bandwidth, whereas a system B application supports streaming to a higher bandwidth. It is certainly possible to downgrade the content to lower resolution. Yet when transmission delays are not of concern, an alternative is to stream a hi-fi sound or a higher resolution picture from the server to buffer the high bandwidth data before playback to the customer.

In addition, the QoS requirements set from the originating network to be honored in any transit networks and in the destination network. The parameters for some QoS may not match exactly between different networks. They may then be hurried across different networks by picking parameters with the closest match to the meaning of the QoS in the previous network.

In 2), the system needs to handle personal mobility and security. Personal mobility in general enables customer B to use the same address in different devices. It requires the network to know that customer B who was previously associated with a certain device is now using a different device, so that the data destined to customer B needs to be redirected to the address of the other device that B is now associated with. In this case however, the new device belongs to a different network A. Therefore customer B needs to be authenticated in network system A whereas the secured customer data were stored in network system B. An example of handling such a security problem between WLAN and the CDMA2000 network was discussed in [1].

In 3), part of the additional requirements is described as service mobility. The implication of service mobility usually deals with configuration in that the user is presented with the same set of services from all end-points.

For interworking between different network systems here, a more general requirement stated here is that the customer B who is now using device A in network A is also able to use an application B supported in network B but may be usually not available in network A. For an example, assume that customer B is used to making phone calls using one’s home network B. Now customer B is inside a building with WLAN. Customer B is now using a computer with WLAN connection, and is trying to make a phone call or to receive a phone call with that computer. As of year 2004, making a phone call with a computer is sophisticated if not difficult. Although some software does enable exchange of voice messages, the quality (as of year 2004) is not yet comparable to that of a phone line.

With the business motivations stated above for interworking, we anticipate that making a phone call this way should give the customer the same service and the process will be as user friendly as making a phone call with a cellular phone. The requirement stated here may call for different implementations. One implementation would be that device A be equipped with all the capabilities and services as device B, if possible. Yet there is still the possibility that the application B is usually not supported in network system provider A for reasons such as licensing etc. In this case, a possible implementation is to automatically download a use-once-only software version of the original application through its broadband network. The program is likely to be an embedded program so that it can execute on its own. The program is also likely to be restricted to use once only during the session of customer B and may automatically be removed after the session so that copyright is not violated.

In 4), the additional requirements involve terminal mobility, which was defined to allow users to move from one location to another while having the same set of services available.

Personal mobility involves additional roaming and handover (or handoff) requirements, which may be subdivided into the following:

4-1) Customers of network B may request the service (turn on equipment) from the new network A and was not connected to network A or B prior to that.

4-2) Customers of network B may request the service from the new network A while the equipment has already been turned on from network B but the requested application was not running.

4-3) Customers of network B may request the service from the new network A while the equipment has already been running using network B. In order words, the application is seamlessly handed off from network B to network A.

These three handover requirements are organized in Table 3.

Table 3. Handover requirements.

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<th>4-1</th>
<th>4-2</th>
<th>4-3</th>
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<tbody>
<tr>
<td>Device has already been connected to prior network?</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Application has already been running?</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>

In all these cases, there are requirements for security and for charging.

As the customer logs into another network (roaming), the customer needs to be authenticated in the new network using the data from the home network.

For charging, the new network needs to be able to charge the service. The charge could be through the home network provider or could be for exchange of complementary service between the service providers to support their customers to roam to each other’s network. The charging policy may differ depending on the service agreements among these providers.
In (4-2), a customer may or may not be required to log in again, depending on the service subscription agreement, the type of service, and customer preferences possibly stored in a customer configuration file in the home network.

For example, customer using device connected to WLAN may move to another location outside the range of WLAN but covered by a 3G Wireless network. Interworking these wireless networks require this customer be connected to the 3G network now, and it may also be desirable that the login to the new network be automated without evening prompting the customer. The customer may then walk to another building served by yet another WLAN network. The 3G Wireless network will hand over the connection to this new WLAN network. The customer is authenticated to access this new network possibly behind the screen.

In (4-3), the customer B using an application is moving from one network to another. The network needs to hang over the customer from one network to the different network without interruption of service to the active application. For example, a WLAN customer making a phone call in a building may walk to another building while the phone call is going on. The customer may find no WLAN service in between the two buildings, but the phone call can continue without interruption if the 3G Wireless service is available to bridge between the buildings.

V. CONCLUSIONS

Interworking WLAN and PLMN Wireless is a cost effective solution to provide more services to more customers. The general requirements of interworking are discussed here.

REFERENCES


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