Transparent Data Service with Multiple Wireless Access

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ABSTRACT

The rapid introduction of digital wireless networks is an important part of the emerging digital communications scene. The introduction of Digital Cellular, LEO and GEO Satellites, and Personal Communications Services poses both a challenge and an opportunity for the data user. On the one hand wireless access will introduce significant new portable data services such as personal notebooks, paging, E-mail, and fax that will put the information age in the user's pocket. On the other hand the challenge of creating a seamless and transparent environment for the user in multiple access environments and across multiple network connections is formidable.

This paper presents a summary of the issues associated with developing techniques and standards that can support transparent and seamless data services. The introduction of data services into the radio world represents a unique mix of RF channel problems, data protocol issues, and network issues. These problems require that experts from each of these disciplines fuse the individual technologies to support these services.

INTRODUCTION

Multimedia wireless Data represents more than just a combination of radio, network and data technologies of which it is composed. These disciplines have evolved in largely independent communities and their fusion is neither obvious nor direct. Each has been spawned with separate technologies and in separate markets. It is only recently that combinations of these disciplines have been merged. Fig. 1 shows how the overlaps of these areas have combined in new techniques and markets.

Cellular telephones, for example, combine the Network switching and Radio technologies for voice applications, while ISDN combines Network switching and Data technologies. The integration of all three disciplines into Multimedia Wireless Data services combines the challenge of operating in the harsh radio environment with the sophisticated protocols required for data, and with the seamless services, switching, and transparency required of modern networks.
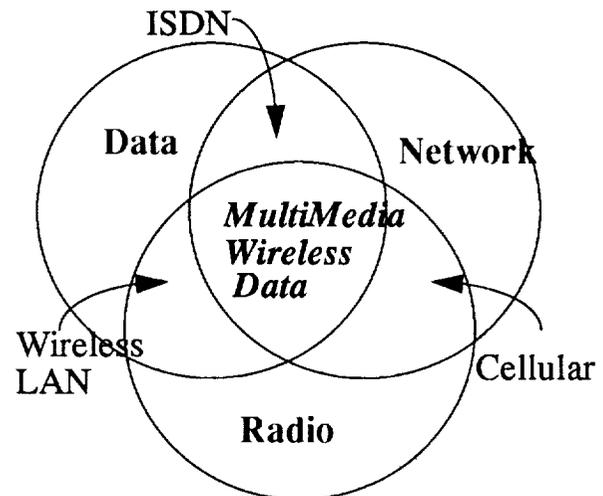

Figure 1. Technologies and Applications

The fusion of these disciplines is particularly challenging in light of the variety of access mechanisms that are possible, as with Cellular, Satellite, and Wireless LAN, each with a separate set of strategies, standards, and problems. The successful integration of these technologies have typically been viewed under the umbrella of Personal Communications Services and Networks (PCS & PCN). While market forecasts for PCS are euphoric, the technical coordination and management problems facing PCS are formidable. Essential to real progress in addressing these problems are first a clear strategy for accomplishing these technical challenges and, second, much greater cooperation among the independent communities of interest. The potential for PCS applications appears un-

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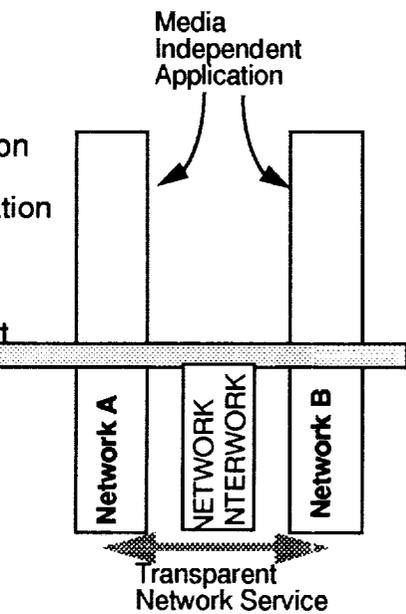cation to interoperable wireless data
l strategy.

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bounded. It offers the possibility for creating a new infrastructure for the Information Age with improved services, convenience, and productivity.

PROBLEM DEFINITION

Besides the historical differences that divide these communities, Cellular Radio, Land Mobile Radio, Mobile Satellite, and Wireless LANs are separated by the perception of a fractured market which may lead in turn to a fractured solution. This highly fractured approach persists today in spite of a high degree of commonality in the architectures, services, and issues. Figure 2 shows an architectural view of these mobile services served by a common public network. They differ in the radio channel and associated protocol but share common services, control, and network interworking features.
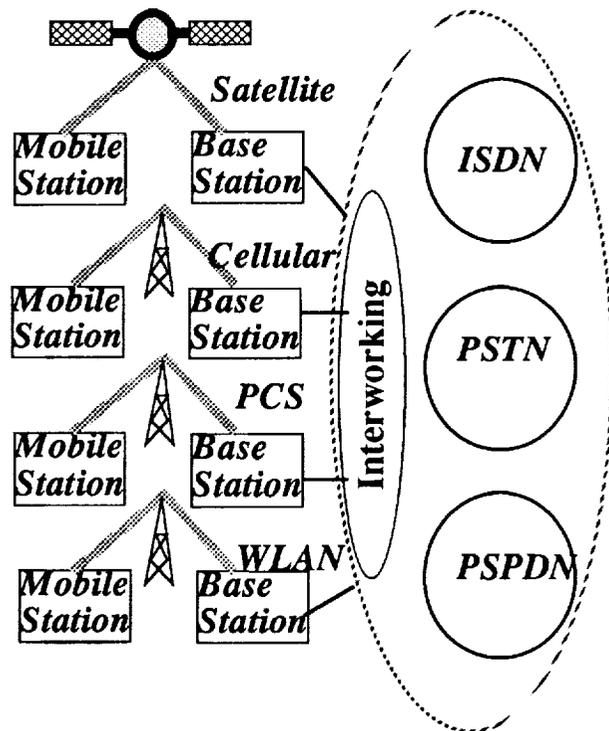

Figure 2 Strategic View of Wireless Networks

These networks and services evolved from independent markets. Their integration with the Public Network has been as ad hoc extensions rather than as part of integrated services. This is true for voice services and is especially true for data services such as G3 Fax. The myriad of approaches taken, for example, by Inmarsat, GSM European Cellular, and TIA North American Digital Cellular

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pendent under TIA 592 by isolating the T4 compression protocol and a piece of the T30 wireline controller. The US Government's secure telephone (STU-III) has likewise been segmented into a media independent protocol for multiple media applications.

The second strategy develops transparent and interoperable networks services and signalling. This is accomplished by access- independent call control, identity validation, registration, and mobility management. Such an approach is recommended by the Joint Experts Meeting of ANSI T1 and TIA TR45 in reference 1 and summarized below in Table 1. Such an approach allows services to be independent of access technologies such as CDMA and TDMA on a given network. It also allows services to be independent of the wireless access network such as satellite or cellular.

Table 1: Media Independence

Access Independent	Access Dependent
Application Protocol	Multiplex Scheme
Call Control	Radio Resource Mgmt
Identity Validation	Radio Link Protocol
Registration/Location	
Flow Control	
Maintenance & Config	

Inherent in such a strategy is transparency to the user and the application by provision of common physical, link and network layers or by automatic interworking capability. This strategy isolates the application from the variety of access RF technologies that will evolve due to competition within markets and the differences among wireless channels.

Figure 4 shows how layering might be accomplished with a G3 Fax connection between the PSTN and a Cellular network. A combination of common applications, common services, network interworking and intelligent networks create a virtual open system for this service.

The Intelligent Network plays a potentially significant role in making operation transparent. The Intelligent Network can support a transparency of service to the user across multiple wireless networks by customizing the connection and inserting the necessary interworking. Operation within the Intelligent Network can incorporate the following phases and functions.

Access Phase - Identify the User/Terminal

    \<User Identity Established\>
    \<Terminal Identity Established\>
    \<User Services Established\>
    \<Terminal Services Established\>

Connection Phase - Customize Network Service
    \<User Dialed Number\>
    \<Examine User/Terminal Services\>

Figure 4: Example of Interoperable Fax Connection - Data Plane
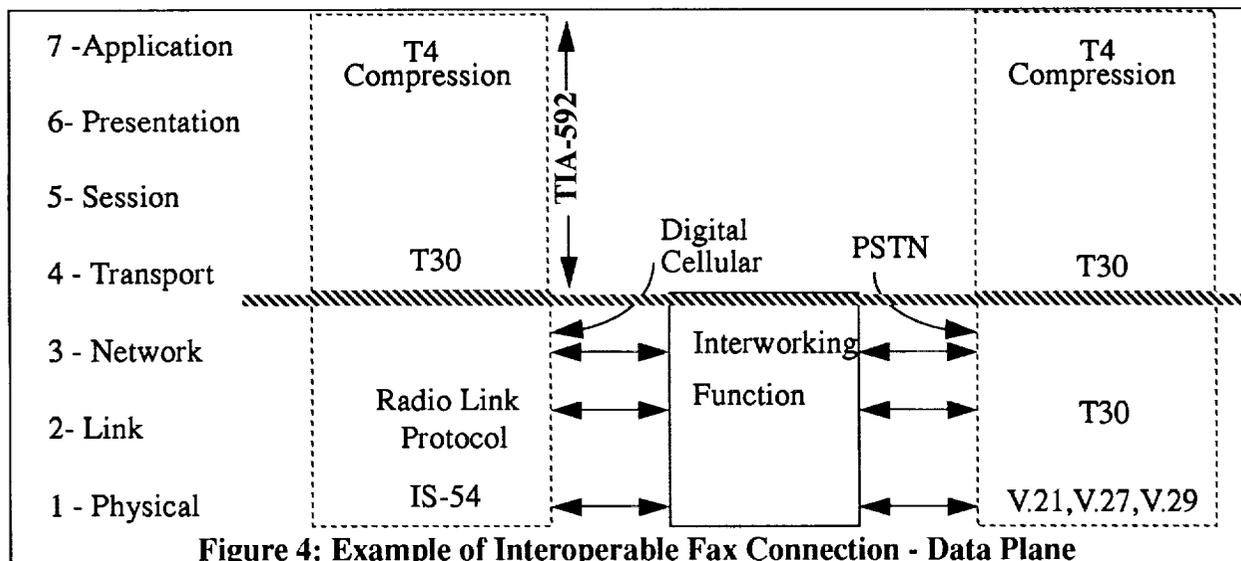
<Examine Destination Network Services>

<Select Service Compatible Option>

Transmission Phase - Support Transparent Service

<Establish Necessary Interworking>

<Clear To Send>

<Data Transmission>

Earlier publications [4] have suggested use of IN services for wireless network mobility subscriber mobility. The above sequence expands that role to support service compatibility, service options, and interworking.

EXAMPLE: TR45.3 DIGITAL CELLULAR

This is not the first paper to suggest strategies for future wireless networks. Most network designers begin with such goals. For this reason it is perhaps more appropriate to search out good example to build upon. The European GSM and North American Digital Cellular TR45.3 are two such examples where this problem has been addressed [2]. Several significant approaches have been demonstrated in TR45.3 in reference [3] and are summarized below.
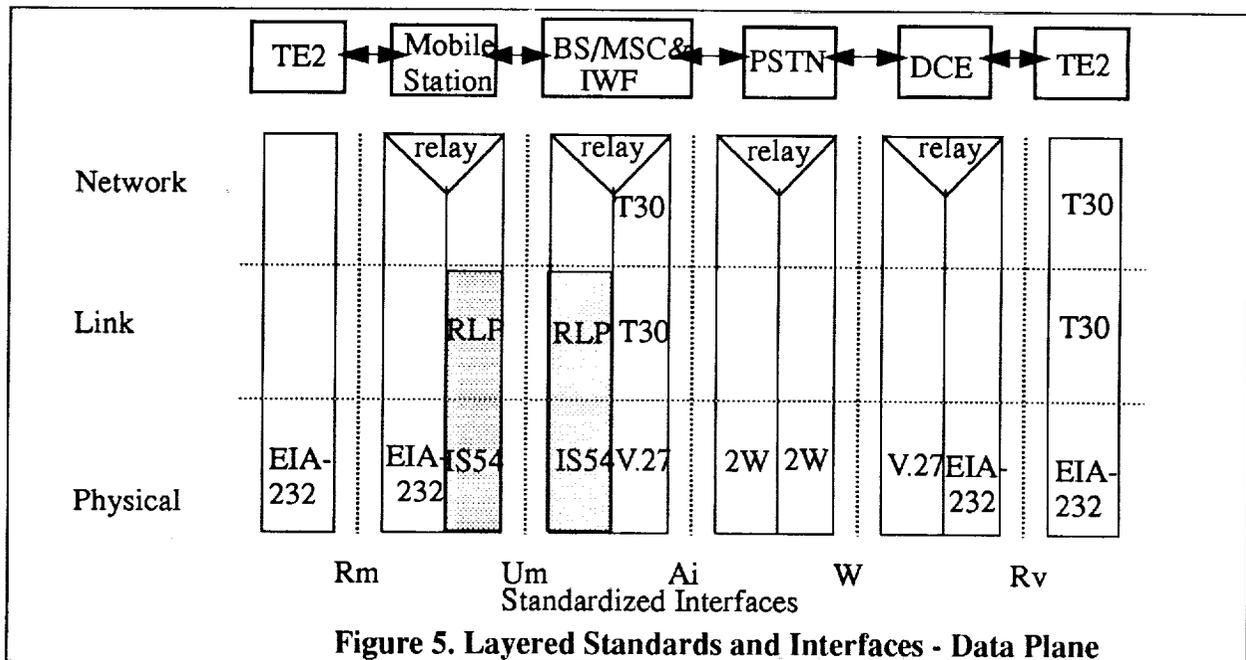
Layered Approach

A layered network model has been developed in TR45.3 to represent each network element needed to support a specific service. The notion of segmenting the network features into layers separates out the network's unique protocols and identifies a means by

which compatibility can be obtained by different manufacturers. The TR45.3 architecture defines the necessary entities for connection to the PSTN using a layered methodology as illustrated in Fig. 5. It represents the lower three layers of the Open Systems Interconnection model, the Physical, Link, and Network Layers. The reference model was adopted at the outset to clearly define the protocols to be supported by the different network elements. Where applicable common accepted data standards and procedures were specified and adapted to the cellular network environment. Figure 5 illustrates the Data Plane protocols used for G3 interoperable Fax service from a Cellular Mobile Terminal Equipment (TE) through the Base Station (BS)/Mobile Switch(MSC) and Interworking Function (IWF). Note how the layering allows clear visibility of the protocols and interfaces necessary at each element in the connection. Note also that the only variation one might expect between a cellular connection and a satellite connection would be in the Radio Link protocol (RLP) unique to that network.

Standard Services

Standard sets of bearer services are necessary across the variety of wireless access networks if transparent teleservices are to be provided. Bearer services would typically be synchronous, asynchronous or packet services necessary to support a broad base of teleservices across multiple networks. Rates

	TE2	Mobile Station	BS/MSC& IWF	PSTN	DCE	TE2
Network		relay	relay / T30	relay	relay	T30
Link		RLP	RLP / T30			T30
Physical	EIA-232	EIA-232 / IS54	IS54 / V.27	2W / 2W	V.27 / EIA-232	EIA-232

Rm Um Ai W Rv
Standardized Interfaces

Figure 5. Layered Standards and Interfaces - Data Plane

from 2.4 up to 28.8 kbps for traditional wireline data, and up to 64kbps for ISDN service are being considered. Custom services such as the G3 Fax and STU-III are also accommodated. A minimum subset of these however can clearly be accommodated across all media.

Network Interworking

Consistent with supporting teleservices identified above is the incorporation of necessary network interworking. Transparent interworking is the most important, and perhaps the most difficult part of the solution. It is at this point that all possible services connect with all possible networks. In general there are a common set of services and connections that simplify this problem. Figure 5 shows a TR45.3 example of Interworking for G3 Fax with the PSTN. The IWF supports a translation of data on the radio link protocol into a V.27 wireline modem with the necessary T30 control signalling to generate G3 compatible service on the PSTN. Other examples of interworking would be use of commonly available V series modems for synchronous service or a Hayes compatible control scheme for asynchronous data. Connections to X.25 Packet networks would require packet assembly-disassembly (PAD) functions. ISDN connections would require V.110 or V.120 rate adaption. The Government's STU-III can be accommodated with a 4.8 kbps synchronous bearer service and an IWF that includes V.21, V.26 and V.32 echo cancelling modems.

Standard Signaling Interfaces and Protocols

Uniformity of signaling, interfaces and protocols across wireless data networks supports common

hardware, services and interoperability. This is perhaps the biggest concern users have about the explosion of wireless technologies. TR45.3 has made a judicious selection of commonly used standards for interfaces and signalling as shown in Fig. 5 and summarized in Table 2.

Table 2: TR45.3 Interfaces & Protocols

Function	Standard	
Mobile Station	Rm	Sm (ISDN)
Signaling	EIA/TIA 602	Q.931. V.120
Rate	.3,2.4,4.8,..38.4	64kbps B Chan
Interface	EIA/TIA 232E	I.430
IWF Modems	V.21,V.22,V.22bis, V.32,V.32bis V.42, V.fast,Bell 103, Bell 212a	

Radio Access Independence

The TR45.3 Data Services have accomplished a large degree of access independence in their designs to date. This is largely a result of a layered approach and represents a major advantage for future applications. Figure 5 shows how the Radio Link Protocol and the IS54 TDMA physical layer are isolated from the other components in the network. This isolation will enable support of the same architecture, protocol and functional elements in the TR45 CDMA solution. It can also be emulated for satellite and PCS networks to support uniformity of products and user services.
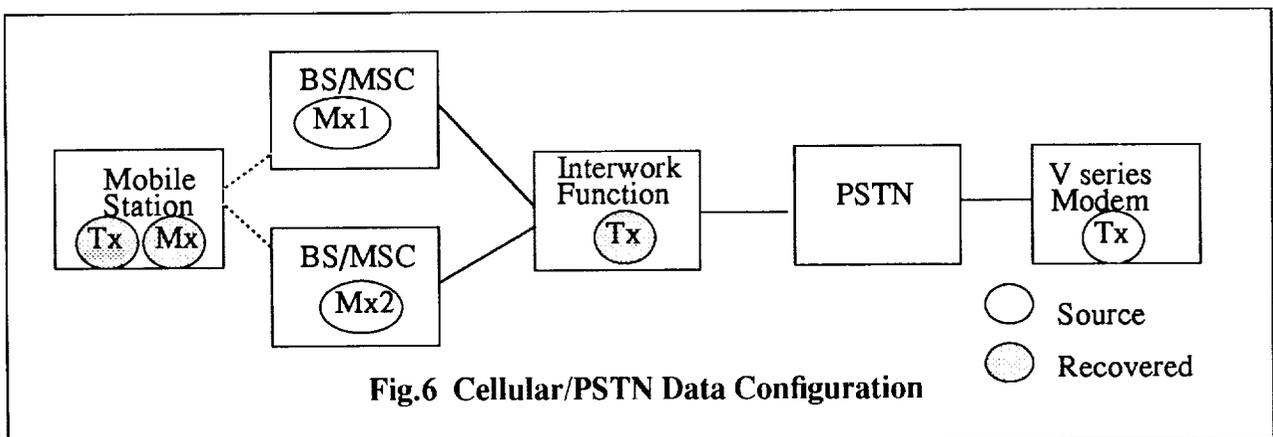

Fig.6 Cellular/PSTN Data Configuration

Timing and Synchronization

Data service for the wireless user connected across the Public Switched Telephone network presents several timing issues that must be resolved. The two significant issues to be addressed are Frame Sync and Bit Sync. Frame sync addresses the need to accommodate timing operation across a handoff. Bit sync addresses the need to accommodate clock mismatches across the network connection. Figure 6 highlights the different clocks in the system which leads to the sync problem in the internetwork connection. The PSTN V series modem transmit clock is shown as Tx and is the data rate of the PSTN source based on that PSTN modem's internal clock. This timing source is tracked by the Interworking Function modem which develops an estimate of this clock using a phase lock loop. This clock is further promulgated across the Cellular channel and appears again in the mobile as a reconstituted Tx. Figure 6 also shows the Digital Cellular synthesized clock Mx. This clock is generated at the MSC and is reconstructed at the mobile station. In general for an agreed upon data rate Mx and Tx are equal to the nominal rate of the data service (E.G. 4.8 kHz). In practice however the data rates of both clocks will differ from the nominal rate and will have some drift. Furthermore, the Mx clock cannot phase lock with the PSTN modem clock as it is locked to the rest of the cellular TDMA system. For PSTN modems the worst case clock accuracy is 1×10^{-4} while the Digital Cellular clock is assumed to be 1×10^{-6} or better. The differences in these clocks results in different transmission rates across the network. This difference can result in a slip in bit sync when there is either too much or too little data at the interface. These differences must be accommodated by the network if the service is to be usable. TR45.3 is currently considering the use of an elastic buffer at the IWF to address this problem. This introduces a modest delay into the connection but isolates the timing problem from the radio link protocol, a clear advantage.

The case shown reflects the situation with the transmission from the PTSN to the Cellular mobile station. Transmission from the mobile station to the PSTN modem represents a very different case. Here the MSC/BS clock can be used to drive both the mobile station and the Interworking function. Furthermore the PTSN modem receiver will track the MSC clock. Hence there is no real issue with bit synchronization in this direction. The bit sync problem as presented here will be common to all mobile networks independent of access scheme.

Frame Sync problems occur in Digital Cellular Networks primarily during handoffs between cell sites that have independent timing references. In general a gap in transmission can occur and the signal will reappear in some random phase alignment. Solutions to the frame sync problem are limited for the TDMA system as the overall timing of the Digital Cellular system is performed independently by each Base Station. The remaining practical solution under consideration in TR45.3 is to maintain frame sync across the handoff by inserting a frame counter in each frame so that added and deleted frame can be accounted for in the alignment of the data stream at the BS/MSC or the Interworking function. A modulo 2^n counter with n ranging from 4 to 8 can accomplish this task. If this scheme is accomplished, the net effect of handoff would be the insertion of burst errors in that data stream when frames are lost but bit sync is maintained.

Conclusions

The standardization of wireless data services represents significant challenges but the potential exists for a smooth path for a broad range of services and markets. Technical solutions lie in a fusion of existing network, radio, and data technologies. A strategy for such a fusion across the multiple wireless networks will require a clear technical strategy as outlined in this paper and, perhaps more importantly, cooperation among the currently insular cellular, satellite, network, and data communities.

References

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