Toward a North American Standard for Mobile Data Services

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Abstract

The rapid introduction of digital mobile communications systems is an important part of the emerging digital communications scene. These developments pose both a potential problem and a challenge. On one hand, these separate market driven developments can result in an uncontrolled mixture of analog and digital links which inhibit data modem services across the mobile/Public Switched network (PSTN). On the other hand, the near coincidence of schedules for development of some of these systems, i.e., Digital Cellular, Mobile Satellite, Land Mobile Radio, and ISDN, provides an opportunity to address interoperability problems by defining interfaces, control, and service standards that are compatible among these new services. In this paper we address the problem of providing data services interoperation between mobile terminals and data devices on the PSTN. The expected data services include G3 Fax, asychronous data, and the government's STU-III secure voice system, and future data services such as ISDN. We address a common architecture and a limited set of issues that are key to interoperable mobile data services. We believe that common mobile data standards will both improve the quality of data service and simplify the systems for manufacturers, data users, and service providers.

Introduction

We are witnessing a revolution in our communication networks infrastructure. After a century of reliance on analog based technology for telecommunications we now live in a mixed analog/digital world and we are rapidly moving toward all digital networks. Mobile communications which includes Cellular Telephone, Mobile Satellite, Land Mobile Radio, and portable telephones the are fastest growing component of the communications industry and are highly dependent on digital techniques. Quite independent of the use of digital technology in the network is the steady advance of data communications in the business and personal world. Today's modem based data communications connect an ever growing number of PCs, Fax and STU-III users. Unfortunately, the intersection of these major trends, mobile data services, requires special accommodation by the networks as simplicity and transparency of analog communications are lost.

A Common Architecture

Today's mobile networks are characterized by a maze of sophisticated techniques and associated standards which address the unique features, channels, control, and switching functions of the various mobile networks. To expect a single standard for such complex and diverse applications is naive. However a segmentation of the network features into layers as has been proposed by others. Reference [1] separates out the network unique transport layer and identifies interfaces which are common to mobile networks and suited to standardization. One such view of mobile networks can be seen in Figure 1 which shows how cellular and satellite networks share common features for data users. Both cellular and satellite networks will have unique features to support operation over the very different radio channels. The interfaces however at the mobile terminal, and at the network interface have quite similar properties and functions. Both must support a compatible transition from the radio link digital protocol to a compatible PSTN modem protocol. Each must deal with detection of control signals and functions which enable transition to and from the data mode into voice. Finally both networks operate with compressed voice at rates below 9.6kbps, and will not directly support analog modem signals. Another view of these same networks is presented in Figure 2 using the CCITT reference model for mobile networks and interfaces. It is significant to note that all mobile connections of interest operate across two very different networks. Here the functions and interfaces for satellite and cellular networks appear common and they could in fact be common. Such models, although insightful, do not replace a detailed specification of interfaces and protocols necessary to insure compatibility. This must happen in standards bodies and reside in detailed standards. What is necessary and can be accomplished here are the identification of the issues which will drive the selection of standard solutions. These are presented below in the interest of forging a common or perhaps standard solution across the many networks.

Interoperability Issues

Initiation of Service

At first glance the initiation of data service is simple. If the initiation is negotiated by voice, the mobile terminal signals the network interface to invoke the interworking function or modem pool. More difficult problems exist however if the service is initiated from the PSTN device or when the devices are not attended. Most PSTN initiated functions will be accompanied by a control tone such as the 2100 Hz tone used by Fax and STU-III. A common solution to all of these situations is to place the data mode initiation and release at the mobile unit. If the mobile unit monitors the analog traffic with a tone detector, the switch to data is straightforward. Likewise if the mobile is unattended it can be strapped for immediate initiation of data service. This solution can only be accommodated if the voice coder used on the radio channel can reproduce the control tones with sufficient fidelity as to assure reliable detection by the mobile unit. This has been tested for the IS-54 VSELP coder as well as the Fed Std 1016 coder and should be a validated feature of other mobile network coders using this scheme and bears further investigation. Other schemes have depended on switching of services by initiation at the network interface. These approaches are limited by the need to identify the service provided by dialed number, or by maintenance of a data base, or the need for two stage dailing. These approaches result in a solution which may be either too awkward or too limiting. For this reason the mobile initiated solution is recommended as a standard for the various mobile networks.

Data Interface and Control

When viewing the CCITT reference model in figure 2 from the perspective of data services, the mobile network represents a "digital pipe" supporting some user defined service into another network interface. The user's interface needs can be totally defined by a specification of:

1. interfaces between the data device and the mobile define as the Sm interface

2. the interface between the mobile and the Base Station (BS) defined as the Um interface and

3. the interface between the Mobile Switching Center (MSC) and the Interworking Function (IWF).

It simply remains to define the form of the interface, the list of control functions and the protocol for communicating control. Following todays standard conventions we would recommend standards for physical and data protocols as shown in Table 1.

Interface	Symbol	Physical Layer	Data Layer
Mobile/Data	Sm	RS-232c	X.25/synch
Mobile/Base	Um	N/A	Service Unique
MSC/IWF	L	RS-232c	X.25/synch

Table 1.: Proposed Common Mobile Interface Standard

The selection of these conventions are clear with the exception of the data layer. Here we are mixing an X.25 protocol which is synchronous with a sychronous mode. No convention appears to be established for such a case.

Given the interface definition and data protocol, there remains only the definition of the message types necessary to initiate and support the service. The first of these would be messages to initiate data service by selecting an Interworking Function. A message format suited to this function is shown in Figure 3 which includes a list of typical selections for the various data fields.

Similarly when connected to an interworking function, a common set of service features would be selected as shown in the message format suggested by Figure 4.

Use of Primitive Data Service Features

The complexity of providing unique data services such as the G3 Fax or the STU-III is not apparent from the control features identified above. In both cases there is a complex interactive set of protocols which propagate into the network functions to support the service. There are for example rate negotiation signaling and rate changes that must be reflected in the radio link operation. In order to remove the complexity of this operation from the link protocols, and to maintain a layered structure, the recommended approach for such data service is to build these services using primitive data service features such as those defined in Figure 4. In this case the radio link is controlled by the mobile data set and the interworking function through a sequential set of appropriate primitive data features to accomplish on the radio link the equivalent of the functions accomplished in the PSTN modem link. This allows a limited set of data primitives to accomplish a wide range of applications. The G3 Fax and the STU-III for example both have synchronous data operation at 2400bps and 4800bps. Figure 5 shows how a G3 Fax connection would be made through the mobile and PSTN networks using the primitives in Figure 4. Although these are quite different standards on the PSTN modem link, they can be identical protocols on the radio link.

Interworking Functions

The role of the Interworking Function shown in Figure 2 is crucial to the operation of data services across mobile networks. These components perform all the necessary functions to translate the protocols and controls from one network to another. Whenever one encounters such a function in a network it is wise to examine the potential complexity that awaits the naive designer. As most of the Interworking

Functions will service modem connections these components are often referred to as modem pools. Ideally there is an Interworking Function for each modem or system protocol offered but in practice these are aggregated into multifuntional programmable devices. Selection of an interworking function as proposed above will invoke a particular protocol set. This must include procedures for accommodating all of the control signals, rate negotiation, channel conditions and timeouts associate with the Interworking protocol. The challenge to network designers is to incorporate as many Interworking Functions possible with a minimum of complexity. For a satellite network an Interworking Function will be located at the satellite ground station. For Cellular applications the implementation of the Interworking Function is complicated by the diversity of locations. A requirement to support many Interworking Functions at a large number of Mobile Switching Centers could be costly and inefficient. The availability of a standard (L) interface as proposed in Table 1 offers the opportunity to centralize this service as shown in Figure 6. Here a T1 connection between the MSC and a remote Interworking Function can support multiple unique data services without directly supporting an IWF at each MSC.

ISDN Interface

Important among Interworking Functions is the interface to ISDN services. This special interface represents the gateway to the future all digital networks and must be carefully planned to assure future data service interoperability. Much of the ISDN Interworking Function requirements are define in CCITT Standard V.110. In addition to protocol issues the major functions addressed in this interworking function are rate adaption, synchronous and asynchronous operation and timing. The IWF defined by V.110 accommodates all conversions of modem bit rates of 75×2^n and multiples of 4000bps to either 56000bps or 64000 bps. Timing adjustments are addressed for asynchronous data. Timing for synchronou data however requires that clock be accepted by the connecting network.

Synchronization and Timing

Timing and synchronization are critical to data operation on mobile networks. Briefly, the issues fall into two categories:

(1) Timing issues, which must be dealt with when synchronous data service connections must cross network boundaries or cross boundaries (*e. g.*, in handoff) within the digital cellular network, where different clocks are controlling timing on opposite sides of a boundary.

(2) Loss of bit count integrity, *e. g.*, as a result of losing a frame in a handoff.

Here we suggest an approach which might be taken to dealing with timing and bit (and frame) count integrity problems by incorporating appropriate control information into the transmission frame structure for applicable data services. The basic concept is to insert frame count (and possible clock timing) information into the channel at uniform intervals tied to the overall frame structure. This information, carried with the frames throughout the mobile system, can be used to resolve frame count ambiguities and clock timing inconsistencies.
Synchronous operation can be maintained across handoffs using a simple frame count technique. It is assumed here that frame synchronism is maintained between any base station and the MSC, but that synchronism is not maintained among base stations. As a consequence of this, a single frame can be lost on handoff. If the frame count ambiguity is in fact no more than plus or minus one frame, a modulo-4 counter (needing two bits of information) can be used to resolve the ambiguity and reconstruct the synchronous data stream when a frame is lost. The implementation would make use of elastic buffers at the MSC and at base stations.

The frame count information could be used to implement a form of "soft handoff". As a mobile is approaching handoff from one base station to a new base station, the frames could be sent to both the current base station and the new base station. As the handoff occurs, the mobile could use the information from the two base stations to resolve the timing differences and achieve a smooth handoff with no dropped frames.

Figure 7 gives a simple example of a frame structure incorporating a frame count field in each frame. In the example, rate-3/8 FEC coding is applied to the 4800 bps data, leaving eight bits for the FRAME COUNTER field, which we show as being coded separately from the user data. If a simple modulo-4 frame count is to be used, an (8,2) binary block code can be used to protect the two information bits. If more information is to be incorporated into the field a different code may be appropriate.

For FEC coding of the user data, either block or convolutional coding could be used. However, block coding might prove to be more convenient to use in conjunction with the frame counting and timing adjustment techniques suggested here.

The basic scheme described above can be used to convey clock timing information in addition to frame count information.

In this case, the information content of the FRAME COUNTER field is expanded to include clock timing information. Given this expanded use for the field, SYNC CONTROL might be a better name. As one example, a clock timing offset between the MSC and the synchronous terminal in the PSTN could be accommodated with buffering and a stuff/unstuff algorithm. The corresponding short/nominal/long adjustment information would be carried in the SYNC CONTROL field. The inclusion of timing information in the frame format would require passing more information than was indicated in the discussion above. This would mean expanding the information content of the control field, and perhaps expanding the overall length of the field as well, in order to provide the desired radio link error protection.. This would be accommodated by reducing somewhat the number of parity check bits allocated to FEC coding of the user information. Since the size of the overhead field will in any event remain relatively small, this should have little impact on provision of adequate link error protection for the user information field.

An approach similar to this is described in a recent conference paper by Shinagawa, *et. al.* [2]. In that paper, a digital mobile radio system under development by NTT is discussed. The paper includes a description of a "hitless handover" scheme in which clock signal information is affixed to TDMA frames and passed between base stations and switching centers.

Conclusions

Fulfillment of the potential for Mobile Networks will only come with careful attention to accommodating the future needs of users. Data services represents a critical component of future mobile service but has received little attention as today's networks are being designed against near term objectives of expanded voice service. In this paper we have outlined a common archetecture for mobile data services and have suggested several reference points in the archetecture that are candidates for standardization. By adopting standard interfaces at the present time when new digital initiates are in the design stage, data service interoperability across a wide variety of networks can be assured.

References

[1] E.S. Chein, D.J.Goodman, J.E.Russell Sr, "Cellular Access Digital Network: Wireless Access to Networks of the Future", IEEE Communications Magazine Vol 25,No.6,pp22-31, June, 1987

[2] N. Shinagawa, et. al., "Digital Mobile Radio Switching System", Paper No. 404.3, presented at IEEE GLOBECOM Conference, San Diego, CA, December 2-5, 1990.

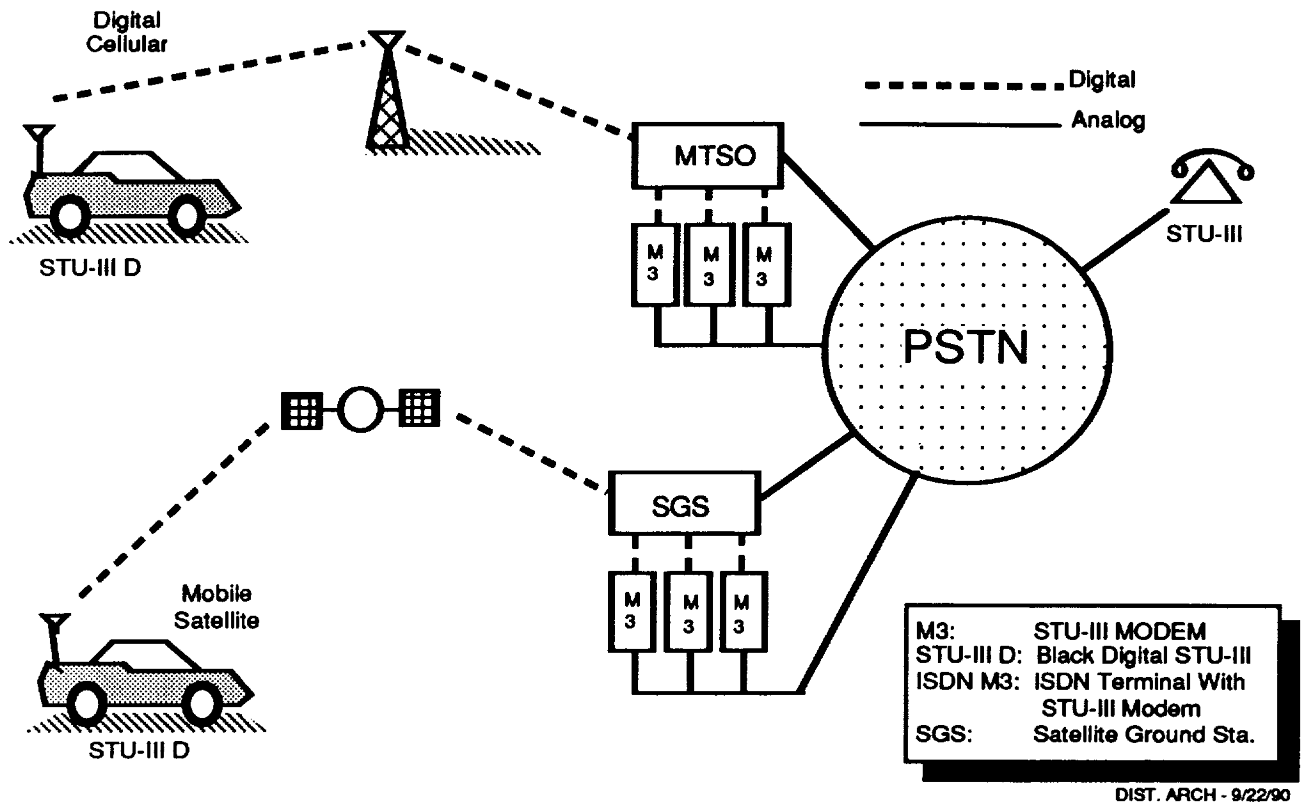

Figure 1. A Common Architecture for Cellular and Satellite

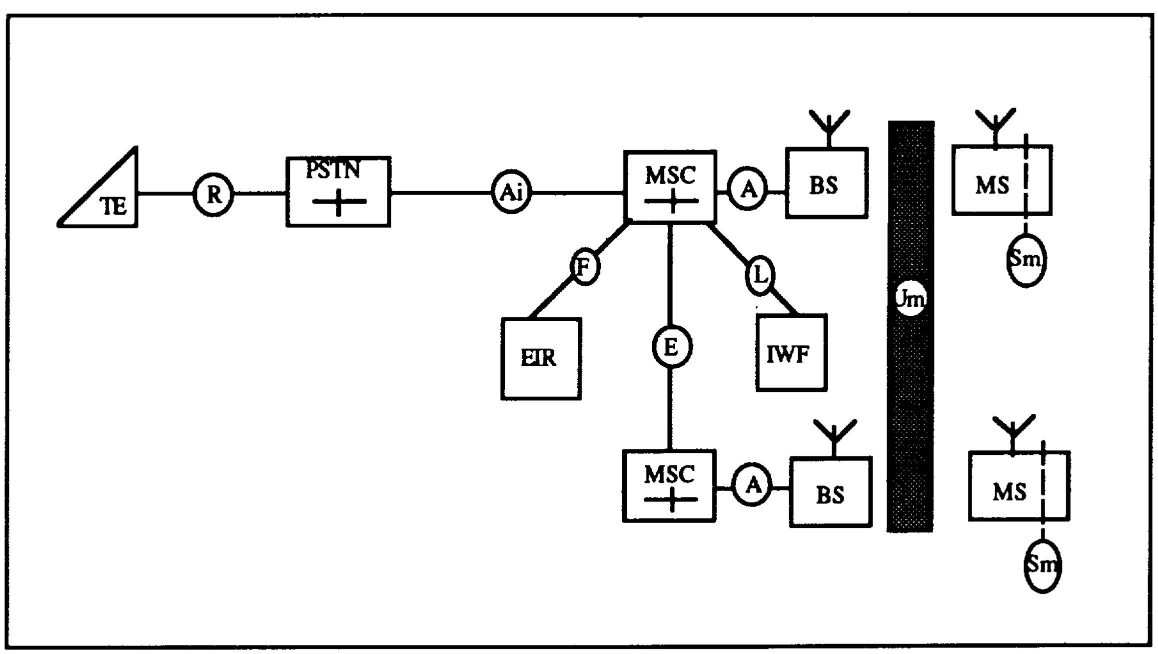

Figure 2. CCITT Reference Model for Mobile Networks

* Message Type	* Service	* Option(N) *
Initiate IWF	G3 Fax	ARQ
Release IWF	Modem Pool	Modem Type
Request to Send	Async data	Duplex
Clear to Send	Synchronous Data	
Service Busy	STU-III	
Service Denied	Raw Channel	
	Revert to Voice	

Figure 3. Selection of Interworking Function

*Message Type	*Rate	*Sync	*ARQ	*EDAC	*Delay*
Service Feature	300bps	async	ARQ	1/8	Short
	1200bps	synch	No ARQ	1/4	Medium
	2400bps			1/2	Long
	4000bps			3/4	
	4800bps			CRC	
	7200bps				
	8000bps				
	9600bps				

Figure 4. Selection of Service Features

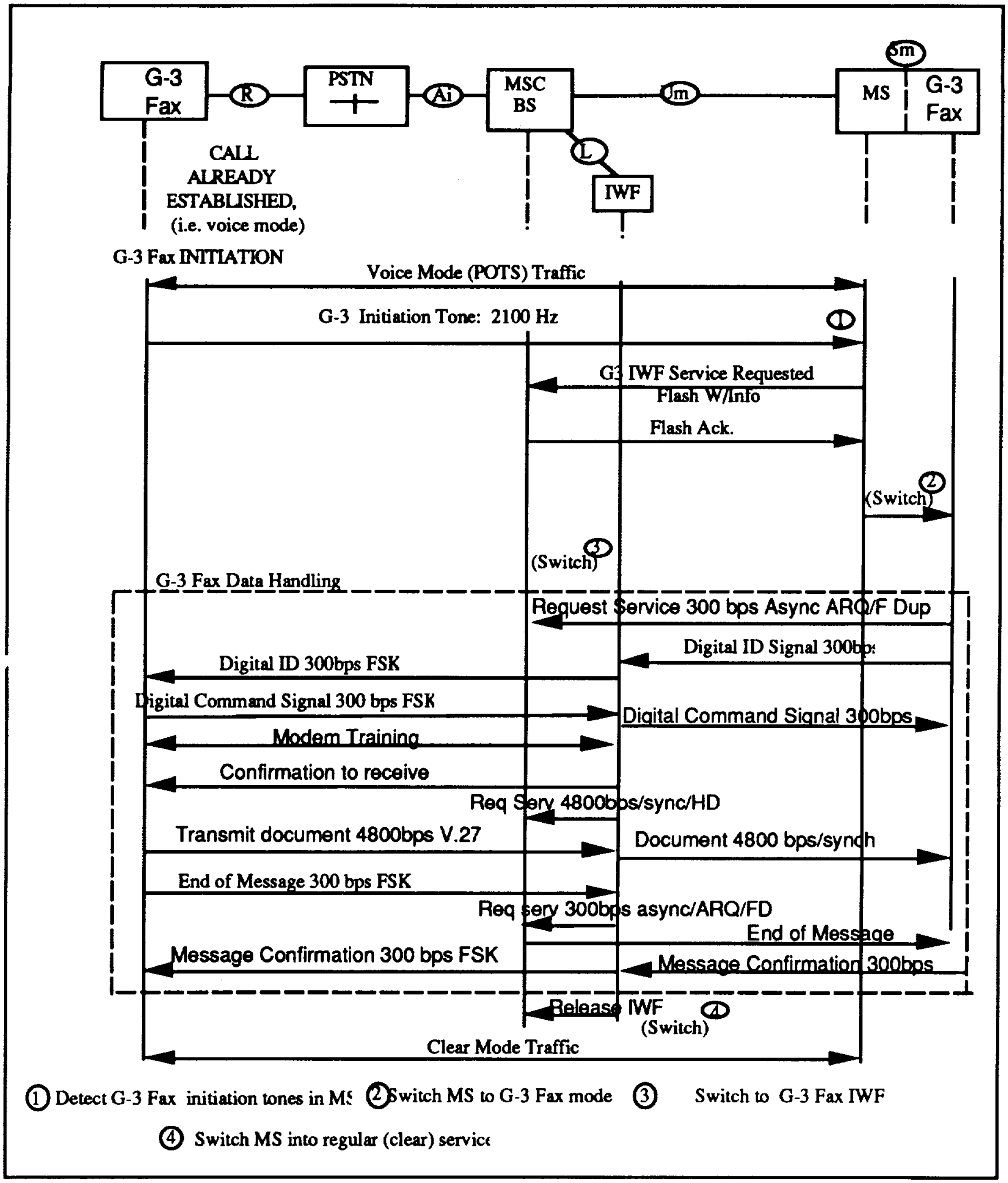

Figure 5. G-3 Fax Connection on Digital Mobile/PSTN Network

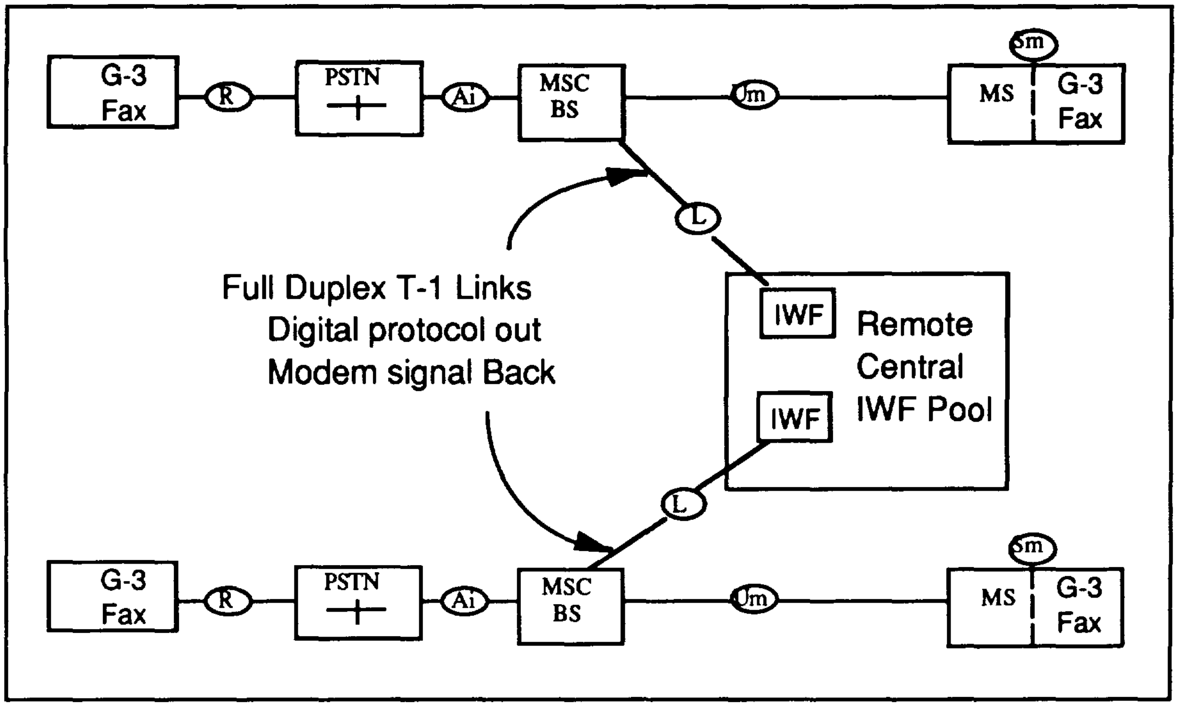

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Figure 6. Centralized Interworking Function

40 ms = 520 BITS AT 13 KBPS		
RATE - 3/8 FEC-CODED		FEC-CODED
USER INFORMATION BITS (192)	FEC PARITY BITS (320)	FRAME COUNTER (8)

***Figure 7.** Example of a Frame Count Scheme for a 4800 bps Synchronous*