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DECNIS PPP Interoperability

Results of the router PPP interoperability tests by RMT Connections Ltd.

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Abstract

This document outlines the Point-to-Point Protocol (PPP) interoperability tests performed by RMT Connections Ltd in December 1993. These tests were carried out on routers from eight vendors and the results will be published in a forthcoming edition of Data Communications International.

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P P P

Interoperability Testing

of Major Router Manufacturers

An investigation into the ability of eight routers from market-leading vendors

to exchange data using the PPP protocol.

RMT Connections Limited

Blackheath, Surrey

January 1994

3Com ↔ **ACC** ↔ **Cisco** ↔ **DEC** ↔ **Eicon** ↔ **Newport** ↔ **Novell** ↔ **Wellfleet**

Appletalk • TCP/IP • Novell IPX • OSI • DECNet IV • Bridging

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1. Summary for the Impatient

This section provides a brief summary of the tests and their results, for those without the time or inclination to read the whole report.

Our objective in running these tests was to establish a simple list showing which PPP implementations will interoperate. We tested a total of eight different products, all of which supported multiple protocols across a PPP link :

1.1. Participants

Supplier	Product/Software	Relevant Protocols
3Com	NetBuilder II	IP, IPX, AppleTalk, DECNetIV, OSI, Bridging
ACC	Nile	IP, IPX, AppleTalk, DECNetIV, Bridging
Cisco	3000	IP, IPX, AppleTalk, DECNet IV, OSI, Bridging
DEC	DECNIS 500	IP, DECNet IV, OSI, Bridging
Eicon	*Interconnect Server for NetWare	IP, IPX AppleTalk
Newport	*Lan2LanMega	IP, IPX, IPXWAN, AppleTalk
Novell	*MPR	IP, IPXWAN, Appletalk, OSI
Wellfleet	Feeder node	IP, IPX, DECNet IV, Bridging

* = PC Based product

The product column indicates the actual router supplied to us for testing purposes. Details of hardware and software versions are given later in the report (Page 22). In the case of manufacturers who implement this same software version across a range of routers, it would be reasonable to assume the test results apply to that range.

The 'relevant protocols' column above indicates only the protocols that were tested, rather than every protocol supported by a router. For example, support for the XNS protocol on a particular router would not be listed as it did not constitute part of these tests.

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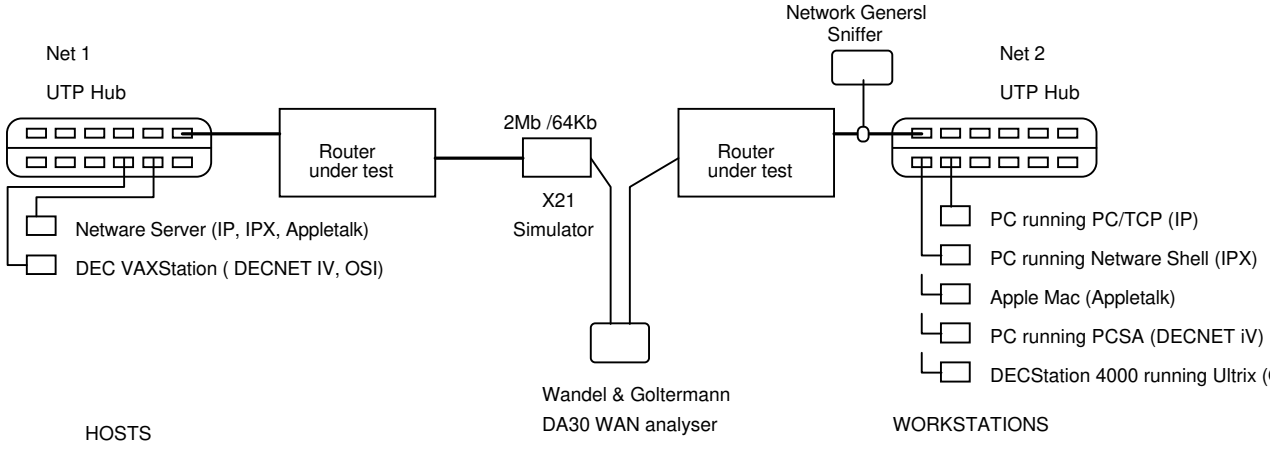
1.2. The Test Bed and Testing Strategy

The test bed is shown below. Two separate Ethernet LANs were set up using Black Box UTP workgroup hubs. The routers under test connected them via a simulated X.21 WAN link, created using a Black Box X.21 modem eliminator. The speed of the WAN link for the majority of tests was set at 64Kbps, as this was supported by all routers.

Various hosts and clients were connected onto the LANs to generate traffic using the different protocols under test. The protocols considered were IP, IPX, AppleTalk, DECNet IV and OSI. Transparent bridging was also tested where applicable.

The hosts were attached to LAN1 as shown on the diagram below, and the clients to LAN2. Data transfers were then initiated between the hosts and clients using the protocols relevant to the routers under test.

Results were monitored using a Wandel & Goltermann DA30 analyser on the WAN and a Network General Sniffer on the LAN(s).



The clients were set up to run automated data transfers to and from the hosts. Each protocol was tested as follows:

IP	Repeated FTP transfers between a Netware 3.11 server running NFS, and a PC/TCP client.
IPX	Repeatedly copying files between a Netware 3.11 file server from a PC client.
Appletalk	Copying folders between a Netware 3.11 server running Netware for Macintosh and a MAC client.

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DECNet IV	Repeatedly copying files between a DEC VAX Station and PCSA client.
OSI	Repeatedly copying files between a DEC VAX Station and a DEC Station 4000 running Ultrix.
Bridging	As for the IPX test, but using non-routed Ethernet II encapsulation.

These transfers were automated, and ran for a period of time to test stability of the PPP link. Protocols were tested individually first and, once working, multiprotocol tests using all the supported protocols between a router pair were initiated.

1.3. Test Objectives

The objective was to test router compatibility over a PPP link. Each router was systematically plugged into the test bed shown above and tested against every other in the following areas:

Activating Lower- and Upper-layer PPP protocols

This ensures that the hardware is compatible, and that the routers can successfully negotiate PPP parameters and support for higher level protocols.

Data Transfer

Once negotiation is complete, data transfer using each protocol was tested. Only the subset of protocols supported by both routers under test was configured and used.

Each protocol was tested first individually, and then alongside all the other protocols supported by the router combination under test.

Abnormal Conditions.

Each router combination was tested for its behaviour under abnormal conditions. These included link failures, unsupported protocols and individual protocol stops and restarts.

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1.4. Test Results Overview

Refer to the matrix on the following page for an 'at a glance' overview of the test results.

Each vendor's router was tested against every other. Each protocol was considered and is represented in the matrix as follows:

IP	- IP	DC	- DECNet IV
IPX	- Novell IPX	OSI	- OSI
AP	-Appletalk	TP	- Transparent Bridging

The results for each protocol and router combination tested fall into one of four categories shown on the matrix key. These are:

Protocol unsupported by one or both routers

Either one of the routers or both, has not implemented this particular protocol over PPP. It therefore could not be tested.

Basic incompatibility in the protocol implementation

Although both routers have implemented this protocol over PPP, there is an incompatibility that prevents it from working. Often this is due to the interpretation of the RFCs relating to PPP, and does not imply that either implementation is incorrect. Detailed explanations follow in later sections.

Problem getting protocol to work

This combination should have worked but for some reason failed. Again, detailed explanations follow in later sections.

Protocol tested successfully

This combination worked and data was successfully transferred as per the tests described in the strategy section.

The 'Link Failure' and 'Unsupported Protocol' tests showed no behaviour which would affect the integrity of a link. All the routers

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were able to recover from a failed circuit; some did not reject protocols as cleanly as they might, and further details of this will be included in the vendor-specific notes sent to each participant.

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PPP Test Matrix - January 1994

	ACC						Cisco						DEC						Eicon						Newport						Novell						Wellfleet					
	IP	IPX	AP	DC	OSI	TP	IP	IPX	AP	DC	OSI	TP	IP	IPX	AP	DC	OSI	TP	IP	IPX	AP	DC	OSI	TP	IP	IPX	AP	DC	OSI	TP	IP	IPX	AP	DC	OSI	TP	IP	IPX	AP	DC	OSI	TP
3Com	Y	Y	1	Y		Y	Y	Y	Y	Y	Y	3	Y	b0	b0	Y	Y	Y	Y	Y	6				Y	Y	Y				Y	b1	Y		Y		Y	Y	b0	Y		Y
Wellfleet	Y	Y	b0	Y		Y	Y	Y	b0	Y		Y	Y	b0	b0	5		b3	Y	Y	b0				Y	Y	b0				Y	b1	b0										
Novell	Y	b1	1				Y	b1	b2		4		Y	b0	b0		Y		Y	b1	b2				Y	Y	b2																
Newport	7	7	b2				Y	Y	Y				Y	b0	b0				Lcp failure																								
Eicon	Y	Y	b2				Y	Y	6				Y	b0	b0																												
DEC	Y	b0	b0	2		Y	Y	b0	b0	Y	Y	b3																														
Cisco	Y	Y	b2	Y		Y																																				

Key

	Protocol unsupported by one or both routers
bn	Basic incompatibility in the protocol implementation
n	Problem getting protocol to work
Y	Protocol tested successfully

Basic Incompatibilities

b0. Not Directly Supported
b1. One uses IPXWAN, other doesn't
b2. One insists on numbered WAN link, the other is half router
b3. DEC wanted 4KB MTU, Wellfleet & Cisco wanted 1600byte MTU

Problems

1. AppleTalk failed - routing info not exchanged
2. DECNet failed - route info seemed OK but no traffic flow
3. Bridging failed - Could not negotiate Bridge NCP
4. OSI failed - Alignment problem of data within PPP frame
5. DECNet failed - Routers see only their End Systems
6. Appletalk failed, routing tables not updated properly
7. LCP started OK, but IP and IPX would not work

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2. Running PPP : technical issues

2.1. PPP Theory

PPP - the Point to Point Protocol - is designed to allow routers from different manufacturers to interoperate over a wide-area link.

The protocol is based on HDLC (High-Level Datalink Control), a very well-established link-layer protocol which provides reliable communications across a serial link. In fact, many router vendors employ HDLC - or derivatives of it - in their products anyway; but HDLC defines no standard way to package higher-level protocols, such as IP or OSI, into the HDLC frame and retrieve them the other end.

PPP resolves precisely this problem. At the lower layers PPP is based on HDLC; but it has been extended slightly to provide a way to indicate exactly which protocol is being carried in a given frame.

The initial, and most important protocol carried across a PPP link has nothing to do with higher-level protocols. LCP, the Link Control Protocol, is responsible for getting two routers initially talking; to establish the sort of packets they want to exchange, and then see which higher-level protocols are to be run across the link.

Once this initial negotiation is complete, actual protocol data for IPX, Appletalk and others can start to flow, still wrapped in a PPP frame. LCP continues, in the background, to verify link quality and allow cessation of a protocol, or bring down the link.

Starting a PPP connection thus involves four phases :

- LCP Negotiation

- LCP Steady State

- Starting higher-level protocols

- Higher-level protocol data flow

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There can be problems at any of these stages, but in general the further two routers get towards the fourth stage, the more compatible they are.

Even reaching the fourth stage doesn't guarantee flawless operation - as will be seen later, end stations can still be prevented from communicating by differences in basic router functionality.

2.2. The RFCs behind PPP

The RFCs which relate to PPP are as follows :

- 1171, 1172 : Initial descriptions of PPP, which describes the rationale, and basic LCP operation
- 1331 : Superseding 1171/2
- 1332 : Defines IP over PPP
- 1362 : Defines Novell IPX over PPP
- 1378 : Defines Appletalk over PPP
- 1376 : Defines DECNet Phase 4 over PPP
- 1377 : Defines OSI over PPP
- 1334 : Defines Authentication protocols for PPP links
- 1333 : Defines ways to monitor PPP link quality.

2.3. Disadvantages of PPP

One of the problems of running PPP - or rather, of running different routers at either end of a link - is that features proprietary to that manufacturer, such as data compression or poll spoofing, are no longer supported. This is a sizeable drawback given the number of such features that vendors are starting to use to differentiate their products. It suggests that PPP will principally be used where buying from different manufacturers provides a more appropriate selection of products - for example, a large backbone router linked to several branch-office systems - than as a choice for linking routers of the same make.

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Beyond this, and the obvious compatibility issues, PPP has no real disadvantages. It is designed to be low-overhead, provides for aligning data on word boundaries, which will

speed processing on some router software and hardware platforms; and is based on a well-accepted protocol, HDLC.

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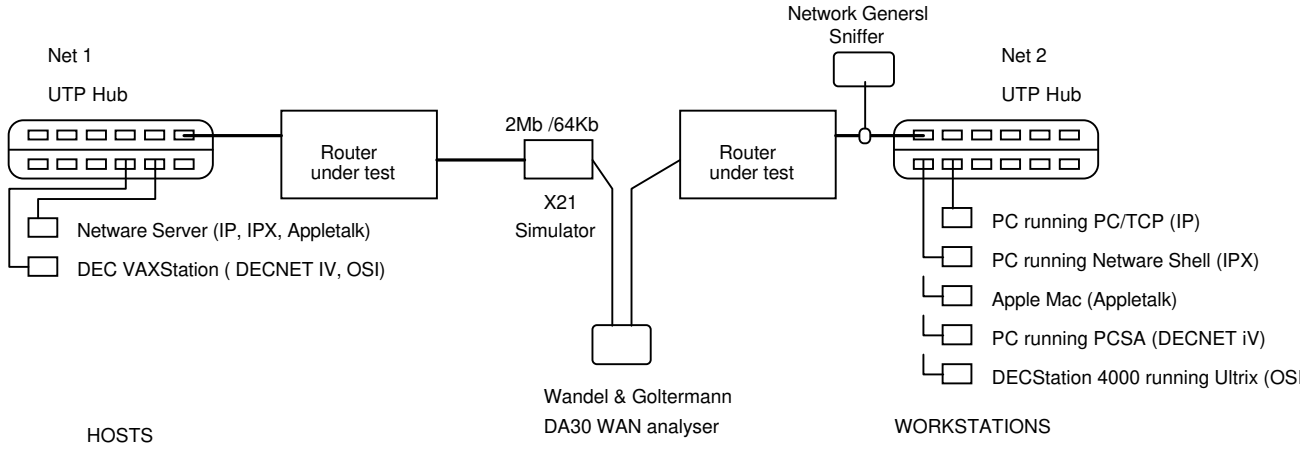
3. The Tests in Detail

3.1. Test Equipment Layout

The test bed is shown below. Two separate Ethernet LANs were created using Black Box UTP workgroup hubs. The routers under test connected the LANs via a simulated X.21 WAN link, set up using a Black Box X.21 modem eliminator. Various hosts and clients were connected onto the LANs.

Our hosts were attached to LAN1 as shown on the diagram below, and clients to LAN2. Data was then transferred between the hosts and clients using the protocols relevant to the routers under test.

Results were monitored using a Wandel & Goltermann DA30 analyser on the WAN, and a Network General Sniffer on the LAN(s).



3.2. Traffic Generation : the Hosts, Clients & Software

Testing involved passing six different types of traffic between the two router-connected LANs :

- TCP/IP
- Novell IPX
- DECNet Phase 4
- Appletalk
- OSI
- Transparent Bridge

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We judged it important to create traffic as close in nature to 'live' LAN traffic as possible. Although it would have been possible to generate traffic for all these protocol types using a LAN analyser, this traffic would not have had the interaction or bi-directional nature of real traffic, and potential problems in the way a router handled the packets might not have shown up.

We therefore used appropriate host and client systems, in all cases, to produce streams of traffic. This meant setting up a number of machines on each side of the PPP link. DEC loaned some host systems to produce OSI (DECNet Phase V) and DECNet-4 traffic, and as a host for TCP, IPX and Appletalk we employed a Novell file server, running the appropriate protocol stacks. The actual equipment, and traffic types, were as follows :

TCP/IP :

386/33 PC Client running FTP's PC/TCP software on an SMC Elite Ethernet adapter;

486/33 PC Host running Novell NetWare 3.11, NetWare NFS Version 1.2b on an SMC Elite Ethernet adapter

Traffic : repeated FTP sessions to transfer files between Host and Client disks.

Novell IPX :

386/33 PC Client running latest VLM shells, NetWare 802.3 encapsulation, on an SMC Elite Ethernet adapter;

486/33 PC File Server running NetWare 3.11 on an SMC Elite Ethernet adapter

Traffic : repeated file copying between server and client disks.

DECNet Phase 4 :

DEC PC Client running Pathworks version 4 under MS-DOS on DEC Ethernet adapter;

DEC VAX-Station 5000 running VMS Version 5.5-2 and Pathworks Version 4.

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Traffic : VAX-Station provided an emulated disk drive to the PCSA client, and the load was generated by repeated file copying between client and server.

OSI :

DEC DECStation 4000 client running Ultrix Version 4.3A and DECNet/OSI Version 5.1A.

DEC VAX-Station 5000 running VMS Version 5.5-2 and DECNet/OSI Version 5.5.

Traffic : Remote logins from the Ultrix to the VAX host; DECNet 'Copy' commands to move data between the two machines.

Appletalk :

Apple Macintosh client running System 7 software

486/33 PC File Server running NetWare 3.11 with the Appletalk stack (NetWare for Macintosh) Version 3.011.

Traffic : repeated copying of large folders (approx 1MByte) between server and client.

Bridging :

'Bridged' traffic was generated by running a Novell NetWare session, between the host and client detailed above. We had originally intended to simply use a different encapsulation (Ethernet V2), which the routers should treat as non-routable and thus bridge (being set to look for 802.3 encapsulation). In practice, all the routers tested simply discarded these packets, until we disabled IPX routing entirely on each one - the V2 packets were recognised as IPX packets and thus not bridged, but then recognised as being the wrong encapsulation and discarded.

We thus tested bridging using NetWare V2 packets, with IPX routing disabled on the routers under test.

3.3. Addressing Details

The network addressing used for the tests was designed to make it as easy as possible to rotate different routers through

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the test-bed, minimising the number of changes necessary for each one. For most protocols, it was necessary to allocate a unique network address to each LAN, and a common network address for the simulated WAN. We therefore allocated a unique range of numbers to each vendor, and asked that routers be pre-configured to the following standard :

Vendor	Range (Decimal)
3Com	*100-109*
ACC	*110-119*
Cisco	*120-129*
DEC	*130-139*
Eicon	*140-149*
Newport	*150-159*
Novell	*160-169*
Wellfleet	*170-179*

The range was used to define a unique number, '(VC)' which was then used to construct addresses for the various protocols, as in the chart below :

Protocol	LAN Port	WAN Port
IP	192.0.(VC).200	192.0.10.(VC)
IPX	Net Number = (VC)	Net Number = 10
Appletalk	(VC).200	10.(VC)
DEC IV	Node Identifier = 1.(VC)	N/A
OSI	Node Identifier = 49::00:01:(MAC Addr):20	N/A

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The Novell router, for example, might be configured as follows:

> LAN IP Address 192.0.160.200, WAN IP Address 192.0.10.160
>
> LAN IPX Network Number 160, WAN IPX Network 10
>
> LAN Appletalk ID 160.200, WAN Appletalk ID 10.160
>
> DECNet IV Node Address (example only, as the Novell router does not support DEC IV) Area 1, Node 160
>
> OSI Node Address : 49::00:01:00608C142003:20, where the twelve-digit address is the MAC address of the Ethernet interface.

Routing protocols were enabled where relevant (RIP for the IP traffic).

3.4. Other Test Equipment

Basic components to build the network were loaned by Black Box Catalogue :

- UTP Ethernet hubs, transceivers and cabling
- X.21 simulators, breakout box and cabling;
- Various 'essentials' such as surge protectors and modems.

A Wandel & Goltermann DA-30 analyser was used to monitor traffic on the WAN circuit. The on-the-fly decodes that this box provides were invaluable in watching the startup (and frequent collapse) of the link, since initial negotiations are very important in determining how a PPP link will function.

A Network General Sniffer Analyser was used to monitor the traffic on the LAN circuit(s). Its ability to provide excellent high level LAN protocol decoding was helpful in understanding problems related to the individual protocols.

3.5. Test Procedures

Four stages must be examined when initiating a PPP link:

Stage 1: Electrical compatibility (Clock speeds, NRZ or NRZI coding for example); When this works, the two routers can exchange frames, reset the link, and try to start a PPP Session. Without it, each side of the link will see garbage from the other.

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Although most of the routers tested were able to run at any speed from 9.6kBits to 2MBits, we kept to a constant 64KBits throughout the work, to simplify testing.

Stage 2: Successful start of the LCP (Link Control Protocol) layer, a level-2 reliable protocol which acts as a carrier for the different LAN protocols that PPP can carry. This requires that the two routers negotiate a set of options on which both can agree, such as maximum packet size, or magic number.

LCP should then settle into a steady, stable state, and the routers can attempt to start higher level protocols, such as IP or IPX, over the LCP layer.

Stage 3: Successful negotiation of higher-level protocols. Each higher level protocol has its own control protocol (for example, IPCP for IP, ATCP for Appletalk). Each router must request a start for a given protocol on the link (eg IPX), using the appropriate control protocol, and must receive either an agreement or non-agreement from its partner. Some protocols support negotiated options at this stage, too - for example, negotiating an IPX Network Number for the WAN link - and this must complete properly.

Stage 4: Finally, when PPP is up and running, the two routers must exchange data and routing information for the successfully negotiated protocol(s). This is not as easy as it sounds, and was probably the biggest cause of obstacles in getting pairs of routers to successfully communicate. Even though PPP may be 'up' and providing a solid, reliable pipe, there may be differences in the way different routers implement a particular protocol which prevent data being exchanged.

Testing, then, examined startup of the link to ensure that the first three of the above stages completed properly. Attempts were then made to pass data across the resulting internetwork as per stage 4 above to check that the routers were fully compatible. The test data itself is described in section 3.2.

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Where necessary, parameters were adjusted to make the link work. This was frequently required (see the results section).

In configuring the routers, where possible, we enabled all of the protocols supported by that combination of routers at one time, to see if this 'maximum' setup was stable.

Where we were able to, we also checked to see how a router dealt with two problem situations :

- Where one router tried to negotiate a protocol which the other does not support;
- Where the PPP link fails for a few seconds, and then is restored.

Once the link was up and running, with data flowing, it was left untouched for fifteen to twenty minutes to ensure that it was stable. This period is clearly not representative of the time the routers would be expected to stay up in a business environment, but much longer periods were not practical during testing. This length of time was chosen as being sufficient for any routing problems or counter-timer problems to make themselves known.

The test-bed was then disconnected and the next router combination set up.

Test Procedure Summary

In summary, the following steps were executed for every possible router combination:

- Connect routers into test bed
- Configure all compatible protocols on a PPP link;
- Make necessary configuration changes for compatibility;
- Check for successful passing of frames between routers;
- Check for successful start of LCP and option negotiation;
- Allow to stabilise

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- Check for successful negotiation of protocols (IP, IPX etc)
- Attempt to pass data over the link
- Allow to stabilise and pass data over link continuously using all available protocols simultaneously for 15-20 minutes
- Check effect of link failure, and bad-protocol negotiation
- Tear down and cycle to next router.

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4. Test Results

4.1. General Comments

In general, the results were very encouraging. Virtually every router tested was able to start and maintain a stable LCP session with every other router : most of the 'No Go' squares in our compatibility matrix are there because a vendor doesn't offer that protocol over PPP, rather than for some deeper technical reasons. Where a pair of vendors do implement a given protocol on a PPP link, more often than not they will be compatible.

The remaining incompatibilities fall broadly into three categories.

Early Implementations

A number of combinations do not work because vendors are early in their PPP implementations, or simply haven't caught up yet. It's important to appreciate that PPP is a relatively young standard; in particular the RFCs which govern the transmission of protocols other than TCP/IP are very new.

Whilst just about everybodies' IP over PPP talks to everyone else, protocols such as IPX or OSI are only just settling down. Some vendors have implemented a given protocol over PPP before the relevant RFC appeared, causing clashes with others who waited for the standard to be published. For example, Novell's OSI over PPP was produced before the OSI RFC was published, and so there's no support for the 'Alignment' option. This causes no problems talking to 3Com, who accept but don't ask for the option; but with Cisco, who expect the option to be supported, the link will not pass traffic.

Incompatible Options

Most vendors have gone for a simple PPP implementation, which offers few options or, in some cases, won't negotiate on any. In this case, the PPP standard is really at fault : there are many optional parts to the RFCs, which a router can choose to support, or just not implement. Both approaches result in routers

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which are 'PPP Compliant', but which may well not talk to one another. A good example is the DEC router's insistence on large packet sizes (over 4KBytes) for some hardware configurations if Bridging is configured over PPP. Some routers, for example the Cisco, won't support packets this big.

Protocol Incompatibilities

The final category is more worrying. This category covers router pairs which successfully start LCP, and then start other protocols over it, but which can't exchange data because the basic way in which they implement the protocols themselves is different. This has nothing to do with PPP, or how the vendor does it. For example, many vendors had incompatibilities with Appletalk. Their versions were perfectly good, but the Appletalk standard allows WAN links to be either un-numbered - the so-called 'Half Router' approach - or to have a network number like any other segment. Routers that take the former approach - for example, ACC - won't talk to those that run numbered links, like Eicon.

This is worrying because while most vendors will probably be keen to fix problems in PPP code, a relatively 'stand alone' section of their router software, they may be more reluctant to fix incompatibilities which arise from core routing functionality.

4.2. Results Matrix

The results are presented in matrix form opposite. The layout is straightforward, with compatibility of a given router pair found by locating the intersection of that row and column. Each protocol for that combination is then marked to show how well it fares.

Please refer to the key on the matrix and the explanations for a full explanation of the failing combinations.

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PPP Test Matrix - January 1994

	ACC					Cisco					DEC					Eicon					Newport					Novell					Wellfleet				
	IP	IPX	AP	DC	OSI	TP	IP	IPX	AP	DC	OSI	TP	IP	IPX	AP	DC	OSI	TP	IP	IPX	AP	DC	OSI	TP	IP	IPX	AP	DC	OSI	TP	IP	IPX	AP	DC	OSI	TP
3Com	Y	Y	1	Y		Y	Y	Y	Y	Y	Y	3	Y	b0	b0	Y	Y	Y	Y	Y	6				Y	Y	Y				Y	b1	Y		Y		Y	Y	b0	Y		Y
Wellfleet	Y	Y	b0	Y		Y	Y	Y	b0	Y		Y	Y	b0	b0	5		b3	Y	Y	b0				Y	Y	b0				Y	b1	b0								
Novell	Y	b1	1				Y	b1	b2		4		Y	b0	b0		Y		Y	b1	b2				Y	Y	b2														
Newport	7	7	b2				Y	Y	Y				Y	b0	b0				Lcp failure																					
Eicon	Y	Y	b2				Y	Y	6				Y	b0	b0																									
DEC	Y	b0	b0	2		Y	Y	b0	b0	Y	Y	b3																												
Cisco	Y	Y	b2	Y		Y																																	

Key

	Protocol unsupported by one or both routers
bn	Basic incompatibility in the protocol implementation
n	Problem getting protocol to work
Y	Protocol tested successfully

Basic Incompatibilities

b0. Not Directly Supported
b1. One uses IPXWAN, other doesn't
b2. One insists on numbered WAN link, the other is half router
b3. DEC wanted 4KB MTU, Wellfleet & Cisco wanted 1600byte MTU

Problems

1. AppleTalk failed - routing info not exchanged
2. DECNet failed - route info seemed OK but no traffic flow
3. Bridging failed - Could not negotiate Bridge NCP
4. OSI failed - Alignment problem of data within PPP frame
5. DECNet failed - Routers see only their End Systems
6. Appletalk failed, routing tables not updated properly
7. LCP started OK, but IP and IPX would not work

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4.3. Failing combinations

Failures can be grouped into three categories under the following headings:

Protocol unsupported by one or both routers

Those that are obviously not going to work. Either a vendor doesn't support a given protocol, or just doesn't support it over PPP : Eicon don't offer OSI, for example, and DEC don't offer IPX over PPP, except via IP encapsulation .

Basic incompatibility in the protocol implementation

Those which support the protocols concerned, but which through software differences can't interoperate : Novell wanting IPXWAN, for example, versus Cisco's straight IPX implementation. (See Section 4.4 below for a detailed discussion of these basic incompatibilities).

Problem getting protocol to work

Those which should work, but don't - where all the configuration and protocol details suggest that communications should be possible, but things just didn't happen; our only option in these cases was to take a trace of the problem, on the Wandel & Goltermann analyser, and leave it with the vendor's development team.

4.4. Basic Incompatibilities

We show below the basic reasons why some combinations will not interoperate; the specific areas of incompatibility are as follows (these are shaded squares represented by b*n* on the matrix):

IPX WAN (b1 on matrix)

Novell defined the RFC, Number 1362, to define how IPX will run over PPP. This RFC describes support for negotiating a network number for the WAN link, so that network administrators don't have to specifically allocate one for each network. So far, very few other

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vendors support this negotiation: Newport were the only ones to offer it at the time of testing. Other routers seem to use a proprietary encapsulation, probably derived from an early implementation; these non-RFC implementations are remarkably compatible, though.

Most other vendors say that IPXWAN support is coming (see section 4.5). In the meantime, this issue prevented the Novell router from exchanging IPX packets with most other devices.

Appletalk WAN Numbering (b2 on matrix)

WAN Segments in an Appletalk can, according to the RFC, be either full-fledged networks, with a unique number, or just a piece of wire linking two half-routers. Manufacturers vary in which path they take. ACC and Novell run only as half routers; Cisco, Eicon and Newport require a network number while 3Com can be configured to work with either. This is the principal cause of incompatible Apple links.

LCP Packet Sizes (b3 on matrix)

During initial startup of the link, routers can negotiate the maximum packet size that they would like to use during that session. The basic PPP RFC states that any router must be able to support the minimum size of 1500 bytes, but that a larger size can be used if both sides agree.

We found numerous problems in the negotiation of this parameter. Some routers insist on working with a particular frame size and will not negotiate (eg the Cisco 3000). This is perfectly legal, but other routers (also legally) try to negotiate larger sizes, not starting the link until this is accomplished.

4.5. Link Failure and Protocol Termination

Brief link failures caused no problems to any of our test pairs : all recovered after a few seconds. We noticed a mix of behaviours when faced with an un-supported protocol, however; although none would affect the viability of a link, some need to be 'tidied' and information on these has been included with each vendor's product-specific notes.

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4.6. Issues on Specific Routers

It is also interesting to summarise quirks and incompatibilities under the heading of each router : more detailed technical information and traces on combinations that should work but don't, are supplied on a vendor-specific basis with this report.

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3Com

Product: NetBuilder II

Software Version: 6.2

Protocols tested : IP, IPX, Appletalk, DECNet IV, OSI, Transparent Bridge

General Comments

One of only two routers to support the full range of protocols we tested (Cisco was the other). The NetBuilder is a standalone box running with either command-line or menu interfaces.

3Com usefully provide flexible support for Appletalk links, talking to both numbered (eg Cisco) and unnumbered (eg Novell) implementations without problems. This was the only aspect of the 3Com needing special consideration for PPP.

Basic Incompatibilities

No IPXWAN support at present. IPX to the Novell router was therefore not viable.

> *IPXWAN support is planned for software release 7.0, due in late February '94.*

Problem Areas

- Despite configuring correctly for unnumbered links, Appletalk to the ACC would not come up, although Appletalk NCP started successfully and appeared OK on the analyser. (3Com did however exchange Appletalk traffic successfully using unnumbered links with the Novell MPR)

- Bridging to the Cisco dropped into a negotiation loop within the Bridge NCP, and never emerged.

- Appletalk to the Eicon router failed to exchange routing information properly, and so traffic wouldn't pass : although 3Com did talk Apple correctly with three other vendors.

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ACC

Product: ACC Nile Multiprotocol Bridge/Router

Software Version: Release 6.3.5

Protocols tested : IP, IPX, Appletalk, DECNet IV, Transparent Bridge

General Comments

The 'Nile' unit is also standalone, using a command line interface.

Its implementation of the Appletalk protocol using unnumbered links means that other routers, where possible, must be configured to match - for example on the 3Com, the 'half router' option must be used.

The ACC accepts large packet sizes, which allowed it to Bridge to every other Bridging router.

One unusual point is that before IP will start to work over a WAN link, the ACC router needs to be explicitly told about its neighbour (the device at the other end of the WAN) : simply listening to RIP broadcasts is not enough. This must be remembered when setting up such connections.

Basic Incompatibilities

- No IPXWAN support at present. IPX to the Novel router was therefore not viable. *IPXWAN support is planned for software release 8, due late summer.*
- Appletalk implementation supports only unnumbered links. Appletalk was therefore not viable to Cisco, Eicon and Newport.

Problem Areas

- ACC 's implementation of Appletalk uses unnumbered links. Although un-numbered links are supported by the Novell and 3Com units, and the Apple NCP came up cleanly, we couldn't make these work, (although Novell and 3Com successfully exchanged Appletalk traffic).

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Cisco

Product: Cisco 3000

Software Version: 9.21

Protocols tested : IP, IPX, Appletalk, DECNet IV, OSI, Transparent Bridge

General Comments

Another standalone unit, the Cisco supports the full range of our test protocols across PPP. Cisco's implementation does not negotiate any options on link startup, which can require care when connecting routers which expect to negotiate on parameters such as packet size. There were no real configuration issues with this router.

Basic Incompatibilities

- No IPXWAN support at present. IPX to the Novell router was therefore not viable. *IPXWAN support is planned in the next software release, 10.0 in April.*
- Appletalk implementation uses numbered links only, so Appletalk was not viable to the Novell or ACC routers.
- Bridging to DEC's 500 was not viable because of the DEC's insistence on large packet sizes on which the Cisco won't negotiate; low-level reconfiguring of the DEC router might have allowed this to work.

Problem Areas

- Bridging to the 3Com would not negotiate, but dropped into a loop;
- OSI to the Novell router would not negotiate successfully, since Novell's OSI software doesn't support an alignment option that the RFC stipulates.
- Appletalk to the Eicon router should work, and did negotiate successfully, but would not exchange traffic. (Appletalk was, however, successful between the Cisco and all other routers where compatible)

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DEC

Product: DECNIS 500

Software Version: V2.2

Protocols tested : IP, DECNet IV, OSI, Transparent Bridge

General Comments

DEC is the only vendor tested to also be an end-system supplier. Perhaps because of this, the DECNIS 500 has some habits which - although ultimately beneficial to end-users - can initially be confusing. If the router receives DEC-4 traffic, and knows it's destined for a host which can talk OSI, the router will convert the traffic into OSI, on the fly, and convert the OSI back to DEC 4 for the return trip.

Another point to watch is that the 500 won't support both DEC-4 type routing (distance vector) and OSI (Link state) at the same time - it's thus difficult to run both DEC 4 and OSI protocols themselves simultaneously. This won't be an issue to DEC users, of course.

DEC support IPX and Appletalk over PPP by encapsulating them in IP. Although the router conforms to the relevant RFCs here, testing these protocols to other routers would have tested only the encapsulation itself, and IP over PPP, so we did not test Apple and Novell protocols.

With bridging configured, the DECNIS we tested insisted on a 4 KByte packet size. To get it working with other routers that don't support this size packet (few do) we had to disable bridging - and of course, this stopped it bridging to several other routers including Wellfleet and Cisco. We later found that this was due to the DECNIS thinking it had FDDI hardware configured (there was no FDDI card present) : although we had no time to try it, removing this statement in the control file should have make the router more amenable to small frames, and thus probably got bridging working with Cisco and Wellfleet (it worked happily enough to the ACC and 3Com, which don't mind large frames).

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DEC are about to ship Version 2.3 of the DECNIS code which supports high-performance IPX routing.

Basic Incompatibilities

- Bridging to the Cisco and Wellfleet failed to negotiate, because of packet size limits (see explanation above).

Problem Areas

- DECNet 4 to the Wellfleet and ACC would not pass traffic, although the link negotiations completed successfully.

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Eicon

Product: Interconnect Server for Netware

Software Version: V3R1

Protocols tested : IP, IPX, Appletalk

General Comments

The Eicon is one of three products based on Novell NetWare file servers : the router runs as an NLM (NetWare Loadable Module) and treats the WAN card as another driver alongside the Ethernet interface.

As an interface to the Novell server, Eicon supports the protocols that Novell' s base router code supports : IPX, IP and Appletalk. It also has access to the same console utilities (ATCON and TCPCON) although the Eicon's configuration is split between a Windows-based PC package, for hardware configuration, and editing a text file on the server to control protocol loading and options.

Basic Incompatibilities

- No IPXWAN support at present. IPX to the Novell router was therefore not viable.

  IPXWAN support is planned for V3R2 due for release in March.

- Appletalk implementation is to use numbered links only. Thus Appletalk was not viable to the Novell or ACC routers.

Problem Areas

- Appletalk would not talk to Cisco and 3Com for un-discovered reasons; Appletalk would negotiate OK but not pass traffic.

- LCP would not come up properly to the Newport router. The LCP configure requests did not complete.

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Newport

Product: Lan2Lan MPR for Netware

Software Version: 3

Protocols tested : IP, IPX, IPXWAN, Appletalk

General Comments

Another PC-based router, running as an NLM beneath NetWare 3 or 4. Newport was the only router to offer both IPX and IPXWAN support. It also handles large packets (4 KBytes) without problems. The Lan2LanMPR also supports compression over PPP, but as this is a proprietary implementation (since there is no standard for compression over PPP currently), this had to be disabled.

Newport's router is unusual in that the default line setting is for NRZI encoding, which needed to be changed to NRZ to match the other routers' default configurations.

Basic Incompatibilities

- Appletalk implementation is to use numbered links only. Thus Appletalk was not viable to the Novell or ACC routers.

Problem Areas

- The Lan2LanMPR failed to establish a stable LCP session with the Eicon router. The LCP configure requests did not complete.
- Although LCP did start successfully to the ACC, neither IP or IPX (the only protocols available to this combination) would exchange traffic. This appeared to be due to an addressing problem on the Newport which caused it to report loopback errors.

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Novell

Product: MPR

Software Version: 2.11

Protocols tested : IP, IPXWAN, Appletalk, OSI

General Comments

Novell have enhanced the basic routing abilities of NetWare with MPR, which adds much more flexibility and OSI support to the platform (also Source Route bridging, which we were not testing). As a NetWare application MPR also uses the Novell console utilities, ATCON, TCPCON and ISOCON.

Basic Incompatibilities

- Required support for IPXWAN stops the MPR exchanging IPX with all but the Newport, which can also support the protocol. Most other vendors say they will support IPXWAN soon (see the appropriate Vendor's write-up for details of this).

- Appletalk links to Cisco, Eicon and Newport are not viable at all because of the Appletalk WAN numbering issue. *Numbered links on Appletalk will be supported on the next MPR release.*

Problem Areas

- OSI to the Cisco negotiates cleanly but can't pass traffic because Cisco uses an Alignment option, valid as part of the RFC, which Novell don't yet support. Novell's OSI implementation was apparently written before the RFC was available. *Support for this option will be in the next MPR release.*

- Despite configuring correctly, Appletalk to the ACC would not work, although LCP and the Appletalk NCP started and appeared OK on the analyser. (Novell did exchange Appletalk with the 3Com successfully).

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Wellfleet

Product: Link Node

Software Version: 5.77

Protocols tested : IP, IPX, DECNet IV, Transparent Bridge

General Comments

We tested Wellfleet's Link Node router, running the Version 5 software. The company's Version 7 software, developed for the Backbone node and in the forthcoming release 7.60 also supporting the VME-based products, supports OSI and Appletalk over PPP.

The Wellfleet's only unusual feature is that the IP routing software expects other routers to support ARP across a WAN - the others we tested don't, and so - a little like the ACC - the Wellfleet must be configured to know about each neighbour by configuring that neighbour as an Adjacent Host.

Basic Incompatibilities

- No IPXWAN support at present. IPX to the Novell router was therefore not viable. *IPXWAN support is planned for 7.60 due for release in February.*
- Bridging to DEC's 500 was not viable because of the DEC's insistence on large packet sizes on which the Wellfleet won't negotiate; low-level reconfiguring of the DEC router might have allowed this to work.

Problem Areas

- DECNet to the DECNIS 500 would not pass traffic; adjacency information did not seem to be exchanging correctly, so that the routers could see their respective End Systems but not each other.

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4.7. General Summary

Routing code is of course in a continuous state of development. Many of the vendors tested have enhancements planned which should resolve some of the above problems.

ACC, 3Com, Cisco, DEC, Eicon and Wellfleet all plan to support IPXWAN in the near future - see Vendor specifics for dates and software release information.

Novell will include support for numbered Appletalk links in their release of MPR; this release will also properly support the OSI Alignment option, making operation with the Cisco viable.

There are clearly several areas where development attention is needed.

The first is in support for Appletalk. Problems here seem to arise partly from the loose specification, which allows numbered or un-numbered links; and partly from indeterminate errors which prevent router pairs from working. There could usefully be some inter-company discussions to find out why this protocol is so hard to get right across PPP. Ideally, the RFC might be tightened to include a 'recommended approach' to implementing the protocol, particularly over Wide-Area links.

DECNet 4 is the other protocol which seems to cause problems. This is a shame because although an old protocol, its simplicity makes it very straightforward to configure.

Another less obvious problem which we encountered during testing was the scattered nature of PPP support : documentation, and test facilities, for the protocol are often spread through the paperwork and command set. PPP is perhaps unusual in that a user tackling it will need threads from many areas of the product - hardware configuration, data for many different protocols, debugging facilities - pulled together; this is hard given the volume of documentation which some vendors now provide.

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5. Final Conclusions

Although in general the level of PPP compatibility we have seen is extremely good, there are enough problems to indicate that people still have some way to go. Fortunately, those problems also help show where most work is needed.

A good part of the blame must lie with the PPP standards themselves, which are surprisingly vague in their definition of what constitutes a PPP-compliant router or bridge. There are many 'Should' and 'May' statements in these standards, and it is to be expected that vendors need to go through one or two iterations before settling on a mutually-agreed subset of worthwhile options.

Perhaps surprisingly, there was little incompatibility at the LCP level : although this is the area where most options apply, most vendors have simply implemented very few or none at all, and so little or no negotiation takes place.

IP turns out to be a very safe bet over PPP, because of LCP's stability and because the IP RFC has been around for some time. Newer RFCs for other protocols, are where the problems creep in.

The only consistent mismatch in the testing was people's lack of support for IPXWAN, and this will be remedied within six months or so - by mid '94 - in most cases.

The most common source of less tractable or unresolved problems is in support for Appletalk, where a small amount of inter-vendor discussion would yield great improvements.

Another barrier to widespread adoption of PPP is the loss of 'bells and whistles' incurred by using it : vendor-specific features like data compression, spoofing, and SDLC or LLC Tunnelling. There is undoubtedly scope for developing the PPP standard to encompass some of these features.

Compression is an especially good first target, since many people will use PPP to connect branch-office-style, small bridges or routers into a larger node. These small routers will only justify slower leased lines, perhaps of 64KBits, where compression is both simple to implement (software compression is effective at these speeds) and very much

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needed. Of the routers we tested Eicon, Newport and 3Com offer this facility at the moment. ACC will be including it in release 7.2 due in May, and Wellfleet in release 7.60 due in February. Both Novell and Cisco spoke to us of planned compression features in forthcoming software as well. The difficulty facing vendors who try to implement compression is that there are no standards defined for it over PPP. Thus each vendor's implementation can for the moment only be proprietary. Many vendors are interested in putting their work forward as a PPP compression standard - a welcome move.

Our testing's bottom line shows a protocol on the verge of stabilising into a truly useful facility : the next few months will see IP, IPX, OSI and DECNet becoming compatible on PPP across a wide range of routers. Some effort to clean up Appletalk and perhaps add software data-compression would make PPP an easy decision for users, particularly those linking smaller branch-office routers into central sites. This work should take higher priority than implementing PPP protocol options; and as a final note to the standards bodies, a truly 'open' PPP options structure which allowed vendors to keep and run their own, proprietary goodies over PPP when talking to their own products would greatly enhance its chances of widespread use.

****

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Our thanks to everybody who lent equipment for these tests : the router vendors themselves, of course; to **DEC** for also sending a pallet-load of VMS and Ultrix hosts; **Black Box Catalogue** for fast despatch of the 'glue' components which linked everything together; **Wandel & Goltermann** for the loan of the invaluable DA-30; and **Equanet** in Chessington for the space to do the work.

Contacts, addresses and phone numbers are given in the Appendix below; English is a stable protocol, so do keep talking.

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6. APPENDIX 1

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