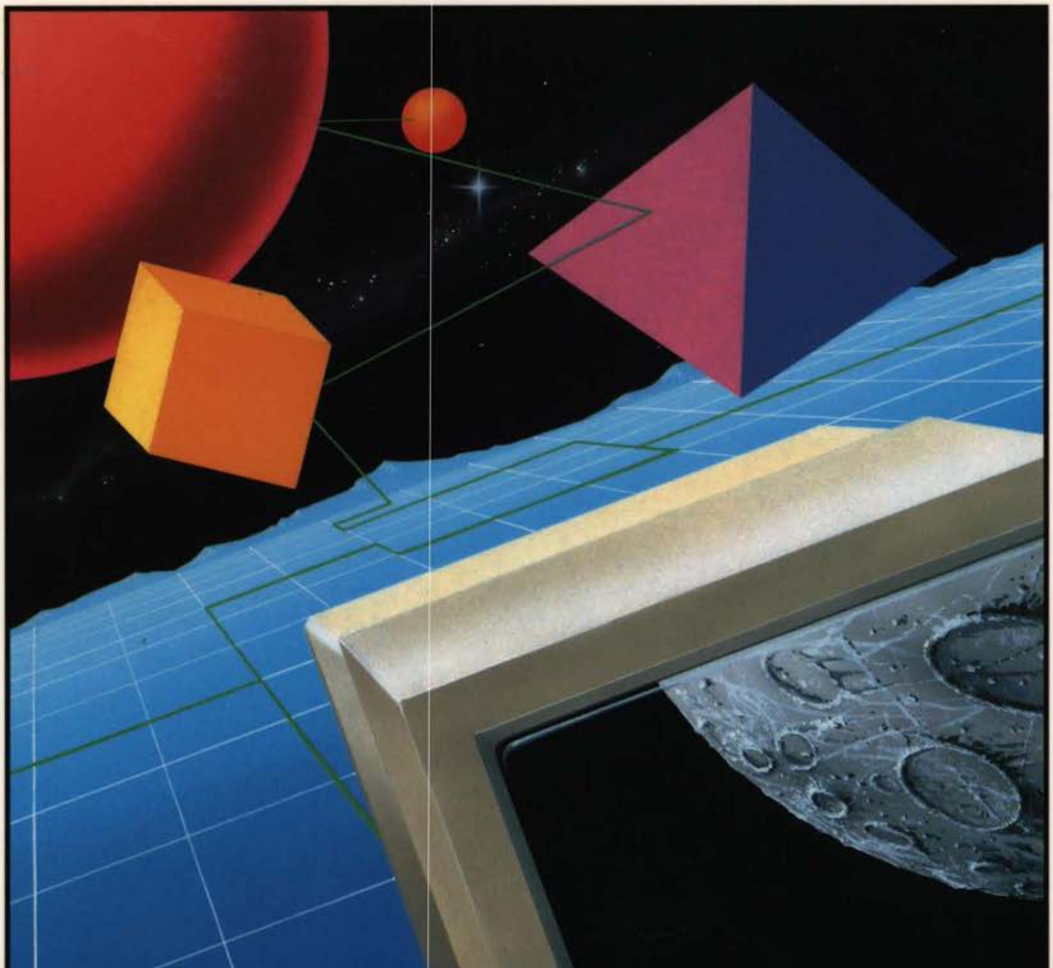
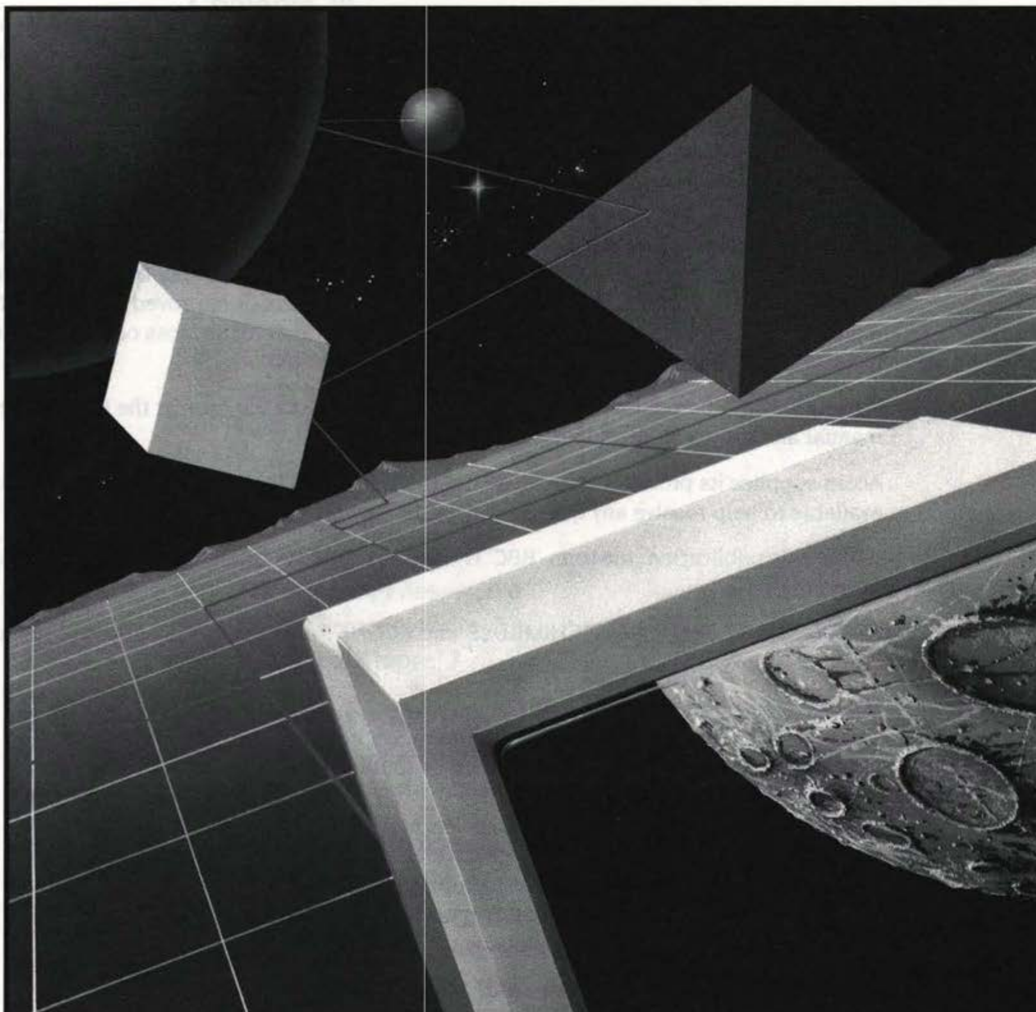
Ethernet Design and Installation Guide



Acorn

Ethernet Design and Installation Guide



Acorn

Published by Acorn Computers Technical Publications Department.

The products described in this manual are not intended for use as a critical component in life support devices or any system in which failure could be expected to result in personal injury.

The products described in this manual are subject to continuous development and improvement. All information of a technical nature and particulars of the products and their use (including the information and particulars in this manual) are given by Acorn Computers Limited in good faith. However, Acorn Computers Limited cannot accept any liability for any loss or damage arising from the use of any information or particulars in this manual, or any incorrect use of the products. All maintenance and service on the products must be carried out by Acorn Computers' authorised dealers or Approved Service Centres. Acorn Computers Limited can accept no liability whatsoever for any loss or damage caused by service, maintenance or repair by unauthorised personnel.

If you have any comments on this manual, please complete the form at the back of the manual and send it to the address given there.

Acorn supplies its products through an international distribution network. Your supplier is available to help resolve any queries you might have.

Within this publication, the term 'BBC' is used as an abbreviation for 'British Broadcasting Corporation'.

Published by Acorn Computers Limited
ISBN1 85250 160 X
Part number 0472,215
Issue 1, July 1994

Contents

About this Guide

This Guide is aimed at network managers of sites that are intending installing an Ethernet network, whether starting from scratch, or replacing a slower network, or extending an existing network. The Guide provides the information you need to liaise with networking specialists so you can get them to design an Ethernet based network that fits your site's requirements, and then to install it. It is not a tutorial in network design, nor does it tell you how to install a network yourself.

Summary of contents

The first part of this Guide takes you through the process of drawing up a proposal, getting tenders for your proposal, and evaluating the tenders to determine which best suits your present and future needs. The second part gives you the background you'll need to talk to the experts and to understand what they're proposing; it includes a useful glossary.

Reader comments

If you have any comments on this Guide, please complete and return the form on the last page to the address given there.

Part 1 – Design and installation

1 Introduction

This chapter gives you a quick introduction to networking, and to the benefits it can bring you. It addresses some of the most basic questions that you may have about networks.

When is the time to network?

For most sites there comes a time when the management of a growing number of stand-alone machines simply becomes impractical and uneconomic. Too much of your time is taken up copying software packages onto numerous hard discs, backing up work, and moving expensive resources – such as printers – from room to room. Work may also be disrupted by users forgetting to bring their floppy discs, accidentally erasing their work, or queuing impatiently to use a printer.

This is the time to network. A network is a means of connecting two or more computers together to enable them to share resources and to communicate seamlessly with each other.

Acorn's Universal Networking (AUN) policy is to provide users with a flexible networking solution that can be tailored to meet their individual requirements and the level of skills that are available. A network can be as small or large, simple or complex, as the situation demands. All AUN products are designed to provide a route for expansion. For more information see the chapter *About* AUN on page 5.

Why network in schools?

Networking provides schools with a means to integrate information technology (IT) firmly into the curriculum. A network provides pupils with instant access to their files, software tools, libraries of information specific to particular subject areas, and hardware resources. It provides teachers with the ability to monitor, control, and protect each pupil's IT activity within the curriculum.

What is Ethernet?

Ethernet is a network technology which is so widely used that it has become the industry standard for the vast majority of computer manufacturers and commercial customers. Ethernet is currently the fastest networking technology that can be used to link Archimedes computers, and the solution that best meets the needs of the majority of Acorn's customers.

What does a typical Ethernet network comprise?

A typical Acorn Ethernet network is composed of several computers, each fitted with the appropriate Ethernet networking card. With suitable software, these computers can then all access any peripherals – such as hard discs and printers – that are connected to any other computer on the network. Alternatively, you can use dedicated secure machines, known as *servers*, to provide resources such as hard disc storage and printers. This requires suitable management software – such as that included in the Level 4 Fileserver package – with which you can then control users' access to and usage of these resources.

How do you design a network?

Careful planning is of paramount importance in order to ensure the network is 'futureproof' and will grow in line with further requirements. It's best to work with networking specialists, who have the experience and skills that are necessary to achieve this. This first part of the Guide takes you step by step through the process of working with such specialists who will design and install your network.

How do you expand a network?

The simplest networks typically comprise a one-room configuration. However, the time might come when your site wishes either to extend the boundaries of your current network, or to link up with networks located in other rooms and buildings. You can do so using standard Ethernet devices such as repeaters, gateways and bridges; again, you should involve networking specialists. (By the way, you'll find brief descriptions of these devices in *Part 2 – Reference* from page 23 onwards.)

Conclusion

There can be no doubt that the wide range of management and control provided by networking brings with it enormous advantages. It will release you from the time consuming pressures of managing many individual machines, and leave you free to attend to the important contribution that Information Technology has to offer your site.

2 About AUN

This chapter gives you some background on *Acorn Universal Networking* (AUN), which is at the core of all Acorn's Ethernet-based networks. It tells you about the different software packages that form a part of AUN, so you can get some idea of which will best suit your needs.

Although this information is complete at the time of going to press, it may not be so by the time you read this. Acorn has a policy of continually expanding and improving the range of its AUN networking products, and new products may be available. For up to date information on AUN products, consult your supplier.

Acorn Access

Acorn Access is a *peer-to-peer* networking system; that is, all computers have equal status:

- Each computer can share its resources – such as hard disc storage or a connected printer – with all the other computers on the network.
  You choose to share such resources by a simple click on a menu.
- Likewise, each computer can use the resources provided by any other computer.
  Choosing which shared resources you wish to access is done using a simple desktop interface, and once you've done so, you can then save your choices for future use.

Acorn's Access range of network products has been designed by Acorn's own networking specialists specifically for simplicity and ease of use. Each Acorn Access pack comes with everything you need to connect a computer to the network. Unlike the other AUN products detailed below, there's no need to configure an address for each station, since this is all done automatically for you.

There is a price to pay for the above simplicity and ease of use, in that there is no authentication of your users (eg with a password), and so you have less control over them than with other AUN products. For example, you can restrict all remote users from accessing a particular file, but you cannot prevent an individual at the hosts from doing so; and you cannot restrict the amount of resources your users consume. (User authentication may be added as an enhancement to future versions of Access, which will remove some of the above restrictions.)

Finally, you should note that Access does not support Econet.

AUN/Level 4 Fileserver

The AUN/Level 4 Fileserver product consists of a number of applications. It is a *client-server* networking system; client stations have a different status to server stations:

- A server provides its resources – such as hard disc storage or a connected printer – to the client computers on the network.

  The server runs an application appropriate to the resource it is providing. The most important are the Level 4 Fileserver, which provides controlled access to disc storage; the Application Accelerator, which provides a fast and secure way of serving applications; and the Spooler, which makes printers available to client stations.
- Each client uses the resources provided by any of the servers on the network. Clients access these resources using established user interfaces based on Econet, so your users that are familiar with Econet won't need to learn new skills. Of course, a given user may not have permission to use all the resources on a network.

As inferred above, AUN/Level 4 Fileserver gives you much greater control over users than does Acorn Access. It does, however, require slightly more work from you to configure the stations and the software.

Finally, this product supports Econet. RISC OS stations that are running this software and are connected to an Econet can access stations connected to Ethernet, and vice versa. (This is done via a *gateway station*, connected to both Econet and Ethernet.) Consequently, any migration from Econet to Ethernet can be done on a step-by step basis, as required and as budgets allow, with minimum disruption. You can replace parts of your Econet with Ethernet, or add new segments of Ethernet; the only apparent change will be in the network's speed. Your investment in existing equipment and training will be maintained.

TCP/IP Protocol Suite

AUN's use of the TCP/IP standard supports the concept of Open Systems, and it is the TCP/IP Protocol Suite that enables you to access **as a client** many of the wide range of services on a TCP/IP network. The key client applications provided are:

- The NFS Filer, with which you can access NFS file servers using a Filer window, just like that used for any other RISC OS filing system.
- The VT220 Terminal Emulator, which (together with the Protocol modules) gives you access to FTP servers, or enables you to use your RISC OS computer as a terminal logged in to another computer.
- MailMan, which enables you to access electronic mail systems.

You're hence only likely to be interested in this software if you intend to connect your computer to a TCP/IP network that has other computers providing these services, such as UNIX workstations and NFS file servers. With the exception of RISC *iX* computers, these servers will have been made by other manufacturers.

You can use this product in conjunction with the AUN/Level 4 Fileserver so that an Acorn AUN network and a conventional TCP/IP network can co-exist on the same Ethernet. Configuring the software for this is described in an application note, available from Acorn Customer Services.

Finding out more

If you need more information on AUN software than is in this chapter, the manuals supplied with AUN software products are available separately. You can thus get the information you need without all the expense of buying the software.

3 Simple networking

Designing and installing any but the simplest of networks requires considerable expertise and knowledge, both technical and practical. If you wish to get good performance from such a network, it's vital that you draw on the skills of networking specialists, rather than attempt to do the work yourself.

The following section – *When you can install your own network* – will help you decide whether your requirements for networking hardware and cabling are simple enough that you can install it all yourself. If your requirements are more complex, we strongly recommend that you get network specialists to do the work for you: either consultants, or dealers specialising in networks. The section *When you need to use networking specialists* on page 10 outlines when you need to do this.

When you can install your own network

You can install your own network if you:

- use thin Ethernet cabling without any trunking (as Access does)
- connect only a small number of stations to the network (less than about twenty or so, although this figure depends on the stations' network usage)
- use a total of less than 185m of cabling to connect the stations
- keep all the cabling indoors.

(Of course, you may prefer to have a specialist do the work anyway.)

If you're installing an Access network, you'll find that each pack has everything you need to connect a machine to the network: a network interface, thin Ethernet cabling and connectors, and simple (but complete) instructions. If the supplied cabling is too short to connect a given pair of stations, you may replace it with a longer one, provided you use genuine thin Ethernet cabling – available from any network supplier. Do not use other types of cabling.

If you're instead using the AUN/Level 4 Fileserver as the basis of your network, you should see the appendix *Simple Installation* at the back of the AUN *Manager's Guide*. This takes you through the process of installing a simple network, right from purchasing suitable network interfaces and cabling from your supplier, through to fitting them.

If you're installing a simple network, you shouldn't need any of the rest of the information in this Guide either to install or to use the network.

When you need to use networking specialists

Unless your network meets the requirements outlined above in *When you can install your own network*, you should get the cabling and hardware installed by a networking specialist. This applies just as much to a complex Access network as it does to any other.

In particular, you should use a specialist if you need or wish to:

- use thick or twisted-pair Ethernet cabling
- use cable trunking (since this usually involves cutting or tapping into the cabling)
- connect a large number of stations to the network (more than about twenty or so, although this figure depends on the stations' network usage)
- use more than 185m of cabling to connect the stations
- connect the new network to a large existing Econet
- divide the network into multiple network segments
- use specialist Ethernet hardware (such as repeaters, hubs, bridges, gateway stations and routers)
- link buildings and/or sites.

The rest of this Guide tells you how to liaise with specialists to get the network that's right for you.

4 Evaluating your needs

This chapter tells you how to evaluate your needs, and hence compose a proposal for tender that specifies your networking requirements. This chapter concentrates particularly on what information any network specialists are likely to need to know, and that you should therefore supply them with, either verbally or as a part of your written requirement.

Surveying your site

The first thing you should do is to look around your site, and gather the answers to the questions below.

Using existing networks

- What existing network(s) do you have?
- Do you wish to have them upgraded in any way (say replacing Econet with Ethernet)?
- Do you wish to connect them to any other networks, either existing or new?

Obviously any network specialist will need to know any plans you have to incorporate your existing networks.

Physical layout

- How large and how far apart are the various rooms that you would like networked?
- If you have to connect together separate buildings, how far apart are they? Are there any obstructions between them that would make laying cables a problem, such as roads or railways? Is there line of sight between the buildings?
- Do you have a false floor and/or ceiling that could be used to route cables?
- Are there any ducts or shafts that can be used to route cables between floors?
- Does your site have any large electrical machinery that may interfere with electrical signals, such as motors, pumps or refrigeration equipment?

The physical layout of your site will strongly influence what type and number of cable segments are required, and hence how much hardware will be needed to connect them together.

Installing other cabling

- Are there any buildings on your site which also need other cabling installed, such as a new building that also requires a telephone system?

If so, it will probably make good economic sense to have all the cabling installed at the same time. Such systems commonly use a structured cabling system, including twisted-pair Ethernet.

Assessing patterns of network usage

As well as the physical details of your site, the pattern of network usage that you foresee is also very important. Consider all the following points:

Numbers of users and stations/servers

- How many users do you have?
- How many stations do you have and/or need, and where?
- How many printers do you have and/or need, and where?

The position and number of stations and/or servers will obviously dictate much of the network's layout.

Network traffic

- Which applications do you use in which physical areas?
- Do any physical areas use the same application(s)?
- Which physical areas need to share data?
- How much disc space would you estimate each physical area requires?
- Which physical areas need to use which printer?

This information, together with the earlier questions, will tell a network specialist how much traffic can be expected over particular parts of the network. Network specialists can use this information to determine the best locations for file and print servers. They can also work out whether and where the network may require partitioning using devices such as bridges. Doing so will prevent local traffic from leaving a particular part of the network, and hence leave the rest of the network free for other traffic.

Choosing your software

One of the most important questions to answer is:

- Which AUN software would you prefer to use?

The various options available are summarised in the chapter *About* AUN on page 5.

Planning your future requirements

Finally, you should consider:

- How might any of the above change in the future?

It's important that you don't install an expensive network, only to find later that it doesn't meet future plans that you could have foreseen when the network was planned.

Writing a proposal

Once you've got all the above information you're ready to write a proposal that specifies your site's networking requirements. The proposal should include as much of the information you've gathered as is relevant, and specify any performance targets that you feel should be met; but it should not specify any particular way of meeting your requirements. This should be left to the expertise of the network specialists who tender for your proposal.

For larger pieces of work, it may be a good idea to split your requirements into several parts, and ask for quotes on each as well as on the whole job. That way, if the work will cost more than you can afford, you can choose which parts to have done now, and which to defer until you can afford them.

When drawing up your proposal, you may find it helpful to get assistance from someone experienced in such matters but independent from those who might tender, such as an Acorn Education Centre or a networking consultant. If you have trouble finding such help, write to Customer Services at Acorn Computers. (The address is given on the form at the back of the Guide.)

An example proposal

Here is an example of what such a proposal may look like:

Introduction

This proposal is for the upgrading of existing networks and installation of new networks in Castledale School.

Background

Castledale School has a long tradition as a local leader in the use of IT across the entire curriculum. However, the school's network is now showing its age, and no longer delivers the performance the school and its 800 pupils need. Applications are slow to load, and many pupils have to keep work on floppy discs for lack of adequate central storage. The recent completion of the Fenley Bottom housing development has led to an expansion of the school: a new Arts block was added last year, and a new Science block is scheduled for completion by the end of May. The school has set aside part of the funding for this growth to refurbish and extend its computer network.

Site layout

The school was formed in 1972 by the merger of Castledale Grammar School (now the Lower School) and Castledale Secondary Modern School (now the Upper School). The Upper and Lower Schools are on opposite sides of Castledale High Street. The main Lower School is a Victorian building, and is supplemented by wartime prefabricated classrooms. The Upper School was built in the 1950s. These buildings are all too old to provide any features that facilitate installing cabling, except that the main Upper School block does have false ceilings that can be relatively easily accessed. A rough plan of each site is appended; more detailed plans are regrettably unavailable, and tenderers may find a site survey advisable.

The new Lower School Arts block has false floors, and trunking around the wall of each room. The new Upper School Science block is similarly equipped. Full plans of both are appended.

Existing networks

The school currently has separate Econets in the Upper and Lower School.

Upper School

The Upper School network consists of three bridged Econet networks:

- **The IT room** has 15 A3000 workstations, a 320MB A5000 Level 4 file server, and an A5000/JP150 print server. All machines are fitted with RISC OS 3.10.
- **The humanities block** has two A3020s in each of six classrooms, served by a 40MB FileStore in the staff area; no printing facilities are available.
- **The music room** has a BBC/Music 5000 system, and three A310s that are still using RISC OS 2; these share use of the Humanities FileStore.

Furthermore:

- **The school offices** have a Novell network to service the school's three IBM PCs and LaserJet 4 printer, used to run Daleside LEA's secondary school administration package (SSAP).

Lower School

The Lower School network has two bridged Econet networks:

- **The science block** has 20 BBC B or Master 128 computers, served by a 30MB Level 3 Fileserver and a Master 128/Epson FX-80 print server.
- **The art room** has four A3020s, and an A5000 that serves both as a 160MB Level 4 file server and a print server for an Integrex ColourJet.

Finally:

- **The mathematics department** have six A4000s in their central resources area, connected together by Ethernet using Acorn Access, and sharing a JP150 printer.
- **Various other rooms** around the Lower School contain a further seven A3020 computers, none of which are networked.

The location of all these rooms is marked on the appended plans.

Tenderers may – if necessary – relocate existing file servers etc to meet this proposal, but the location and type of all workstations should remain as above.

New facilities required

Inter-site link

The Upper and Lower Schools are to be connected with an inter-site link, so the school has just one network.

Econet to be replaced by Ethernet

All RISC OS workstations that currently use Econet are to be converted to use Ethernet, and the buildings appropriately recabled.

Extra storage

The humanities file server has no free space left, and we foresee the need in the near future for some 100MB of extra storage for humanities, and 50MB for the adjacent music room. Other file servers currently have enough space to hold the applications used in their area.

An extra 1MB of storage per pupil is required for them to store their work. To make administration and backup easier the school would prefer that all a pupil's data is held in a single location, provided this does not overly degrade the network's performance. Note that pupils do most of their computer work on their own site.

Extra printers

The IT room requires a colour printer, the output quality of which must be at least as good as the art room's ColourJet printer. The humanities block needs a printer, to be installed in the lobby outside the library, and serve the music room's light usage as well.

New arts block network

The new arts block needs to be connected to the site network. Each room is to have four Ethernet sockets, save for the central IT room which must support 15 workstations. Initially, the IT room is to be fitted with 10 A3020 workstations, a JP150 printer, and access to 200MB of applications that largely coincide with those used in the humanities block.

New science block network

The new science block is to be fitted in the same way as the new arts block, the only difference being that the applications used in the science block are, in the main, not used elsewhere in the school.

Note that the new science block is not currently wired. A separate proposal is available for the telephone and electrical mains system; you are welcome to tender for carrying out both proposals at once.

BBC computers

The applications for the BBC computers in the Lower School science block will always be stored on their local file server. This file server must be accessible from any computer connected to the site network. The BBC/Music 5000 system in the Music room should retain access to at least 20MB of storage, but need not be connected to the site network to achieve this.

School administration network

As a minimum, facilities must be added to allow file transfer between the main site network and the school's Novell administration network. The school would prefer a full transparent link. Any access between the two networks must be secure, as much of the information on the administration network is confidential.

Future requirements

The next major expansion we expect at Castledale School is to connect workstations to the extra sockets in the new arts and science blocks. They will run the same applications as the workstations installed under this proposal.

Performance targets

The installation must meet the requirements of the latest issues of all relevant local and national building, electrical and safety regulations, including:

- ISO/IEC 8802.3: Carrier sense multiple access with collision detection (CSMA/CD) access method and physical layer specification
- ECMA TR/26: Planning and installation guide for CSMA/CD 10Mbit/s baseband LAN coaxial cable systems
- BS 7671: Requirements for electrical installations (IEE Wiring Regulations Sixteenth Edition)
- ISO/IEC 11801: Generic cabling for customer premises (if available), otherwise:

  EIA/TIA 568: Commercial building telecommunication wiring standard (USA standard)

- BS 6301: Specifications for electrical safety requirements for apparatus for connection to telecommunication networks (based on EN41003, with national requirements included)
- Local and national fire regulations (ie the buildings must still meet the requirements of their Fire Certificates).

The site network should be available every school day between the hours of 8.00am and 5.00pm with no significant interruptions to service.

It should be possible for all RISC OS workstations in a particular physical area to load a copy of Impression Style from their local file server within 60 seconds of them being simultaneously powered up. All these stations must be able simultaneously to save a 100kB file to each pupils' work area without any timeouts.

Documentation required

Any installation must be supplied with full documentation, including:

- plans showing the location of all units fitted, and the routing of all network cabling
- details of changes and/or additions made to the mains wiring, and of fusing
- details of transient protection units and earthing arrangements
- names and addresses of all manufacturers used
- all manuals supplied with installed equipment.

Installation dates

We would very much prefer that the network be installed during the school's summer holidays, between the dates of 23rd July 1994 and 5th September 1994 inclusive.

Site visits

Prospective tenderers are welcome to visit the school by appointment to make any necessary site surveys, or to get more detailed information than is given in this proposal. Appointments should be made through Michael James (Castledale School's IT Manager).

Submitting tenders

Tenders are invited for this proposal. All tenders are to be submitted by noon on 17th June 1994. All tenders must include:

- a plan showing how the above requirements are to be met
- an itemised costing showing labour and hardware costs separately for each of the following parts of the work:
  1. the inter-site link (see *Inter-site link* above)
  2. upgrading the current network (see the sections *Econet to be replaced by Ethernet*, *BBC computers*, and *School administration network* above)
  3. increasing the provision of storage and printers on the current network (see *Extra storage* and *Extra printers* above)
  4. installing networks, stations and other hardware in the new arts and science blocks (see *New arts block network* and *New science block network* above)

  as well as a total cost for all the above work
- whether the tenderer has any similar reference sites that we could visit
- performance guarantees (if any) that the tenderer is prepared to give
- firm schedules for installation of the network
- terms and conditions of business.

5 Getting and comparing tenders

Once you've written a proposal for your requirements, you should then invite tenders for it. Ensure that you shop around, and get several tenders. Different specialists will give different solutions, each of which will have different merits and drawbacks, and cost more or less than the others. For example, one might use bridges to connect subnets to a site's backbone network, which will keep local traffic off the backbone; another might use repeaters for the same purpose, which are cheaper, but propagate all network traffic across the entire site.

Having got your tenders, the last stage is to decide which one to take up. Again, you may find it helpful to get assistance from someone experienced in such matters but independent from your tenderers, such as an Acorn Education Centre or a networking consultant. If you have trouble finding such help, write to Customer Services at Acorn Computers. (The address is given on the form at the back of the Guide.)

Comparing tenders

One way of comparing tenders is to draw up a table showing the criteria you consider important, together with a weighting showing how important each criterion is. Then for each tender, score each criterion on a scale of 0 to 10, and multiply that score by the importance weighting. Add up the results to give a total for each tender.

The table below is an example of this:

Criterion	Weighting (1 - 5)	Score (0 - 10)	Weighted score
Price of network installation	4	8	32
Quoted completion date	2	4	8
Quality of hardware	5	7	35
Quality of software	3	5	15
Expected performance	4	9	36
Performance guarantees offered	4	6	24
Impression given by reference site	3	9	27

Criterion	Weighting (1 - 5)	Score (0 - 10)	Weighted score
Degree of future-proofing	4	7	28
Existing relationship with tenderer	1	0	0
Professional approach of tenderer	2	9	18
Business terms	2	3	6
Warranty terms	4	7	28
		Total	257

If you use this method, you should carefully consider what criteria to use, and what weightings to attach to them. Do not blindly copy the criteria and weightings shown above. These will, of necessity, differ from site to site. For example, some sites may have very little money, and so attach a very high weighting to the cost; other sites may be fortunate in having more money, but have a pressing need to have the network installed by a specific date, and so weight completion dates more highly.

You should now know from which tenderer you wish to order your network. Let them do the hard work; it's what you pay them for! When they're finished, enjoy using your new network, and all the benefits it will bring you.

Part 2 – Reference

6 Basic Ethernet hardware

This chapter describes Ethernet cabling, and the ways that various bits of hardware are connected to it.

Together with the next chapter – *Connecting networks* – it will give you the necessary background information to help you understand any recommendations made by dealers and consultants. However, this chapter is **not** a tutorial in network design, and does **not** provide all the information and expertise needed to create a good design.

Reliability

One thing we cannot emphasise too strongly is that the quality of electrical signal on your network – and hence the reliability of the network – depends almost exclusively on the quality of the cabling and connectors you use. Don't skimp and save too much, or you may regret it later!

You must use the correct standard of cabling for the type of network you choose. Resist the temptation to install a cheaper grade of cable which is superficially similar to the specified grade, as your network will not work properly. For example, you mustn't try to run Ethernet over coaxial cable designed for use with TV aerials, even though it may appear similar to the coaxial cables used for thick or thin Ethernet (described on page 27). Likewise, you must use connectors that are designed to meet Ethernet standards.

Don't try to make up cables yourself from cabling and connectors, since this requires specialist tools and knowledge to ensure a good connection. You can't just cut a wire and push it into the connector, nor should you solder wires to connectors.

Types of Ethernet

There are several types of Ethernet: *thick Ethernet* (also known as 10BASE5), *thin Ethernet* (also known as Cheapernet, or as 10BASE2), and *twisted-pair Ethernet* (also known as 10BASET). All can transfer data at the same rate of 10Mbits/s. They differ mainly in their topology (i.e. the layout the network must have) and their cabling.

Topologies

Bus networks

Thick and thin Ethernet are both *bus networks*. All devices connect to a continuous length of cable, which must be fitted with a *terminator* at each end to preserve the quality of electrical signals. Data passes along the cable direct from one device to another:

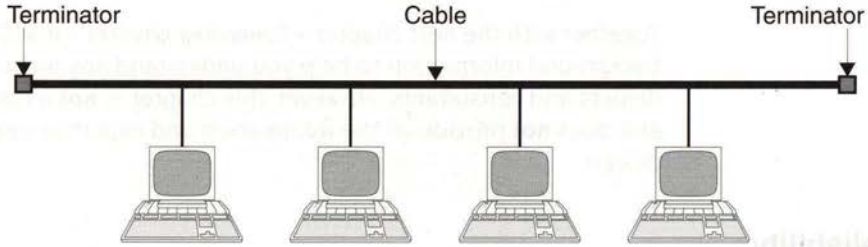


Figure 6.1 Bus topology, as used by thick and thin Ethernet

Star topology

Twisted-pair Ethernet is a star network. This means that instead of there being a single length of cable to which all computers connect, each station must have its own length of cabling which plugs into a central *hub*. The hub is responsible for passing any data it receives to all other connected devices.

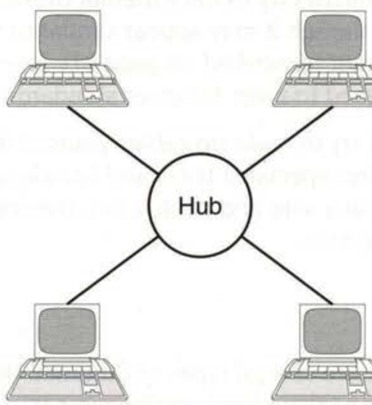


Figure 6.2 Star topology, as used by twisted-pair Ethernet

Cabling

Thick Ethernet

Thick Ethernet uses a thick *coaxial* cable. It is relatively inflexible, having a minimum radius of curvature of about 25cm. It is very resilient to physical damage and to electrical interference.

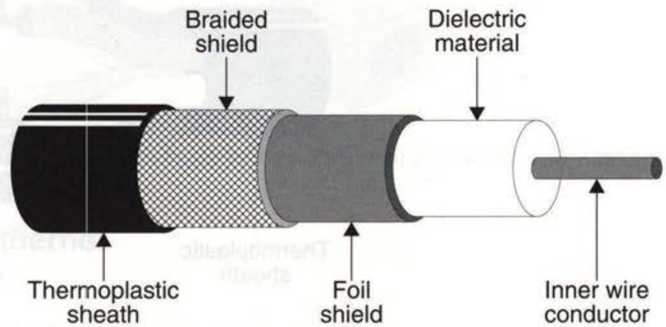


Figure 6.3 A *coaxial cable*

Each cable segment can be up to 500m long, and may have up to 100 connections made to it. Connections must be at least 2.5m apart.

Thick Ethernet cabling is the most expensive of all, but it can support the greatest number of machines over the longest length, and is also the most rugged type. Because of this, thick Ethernet is often used for backbone networks.

Thin Ethernet

Thin Ethernet also uses coaxial cabling (see above), but the cabling is much thinner than that used for thick Ethernet. This makes it comparatively flexible, but also less resilient to physical damage and to electrical interference. Because of its poorer electrical properties it cannot support as many stations over as long a length of cabling as thick Ethernet can.

Each cable segment can only be up to 185m long, and may only have up to 30 connections made to it. However, this is a theoretical maximum, and we recommend that to get acceptable performance you connect no more than 20 stations to a single segment. One advantage of thin Ethernet is that connections may be as close together as 0.5m apart.

The cabling for thin Ethernet (as befits its alternative name of Cheapernet) is less expensive than that for thick Ethernet. Thin Ethernet is typically used to connect together groups of workstations, and for short backbones. It is particularly suitable for installation in an existing building where low cost is an important factor.

Twisted-pair Ethernet

Twisted-pair Ethernet links each device to a hub using a thin and flexible cable that is similar to a telephone cable. Each cable may be up to 100m long. The cable is known as *unshielded twisted-pair*, or UTP for short:

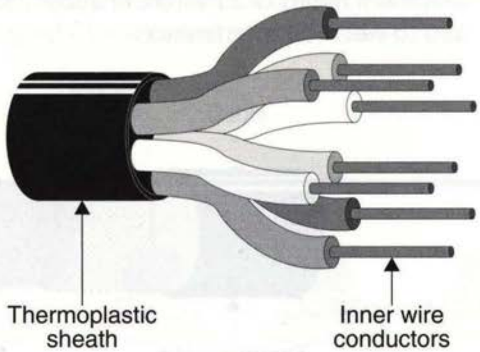


Figure 6.4 An unshielded twisted-pair cable

Twisted-pair Ethernet cabling is the cheapest of all, but purchasing the necessary hubs adds to this cost.

There are various quality levels of UTP cabling. Levels 1 and 2 are not suitable for Ethernet, and are mainly used for telephones. Level 3 can carry data at up to 10Mb/s, and so is suitable for use with Ethernet. Level 4 is capable of 20Mb/s, and so is suitable for a Token Ring network – or, of course, for Ethernet. Level 5 can manage up to 100Mb/s, which is widely predicted to become the new Ethernet standard. Should you decide to use UTP cabling, we recommend that you install Level 5 now. This will cost you little extra, and equip you for the next generation of networking; otherwise you risk the far greater expense of needing to reinstall all your network cabling in a few years time.

Notes

Maximum cable lengths given above include **all** cabling on a given segment, including any used to connect stations to the main segment.

Various ways of protecting cabling from damage – accidental or otherwise – are available from Ethernet suppliers.

Baluns

A *balun* is a small connector used for connecting together dissimilar types of Ethernet cabling. It incorporates a transformer, used to balance the cables' different electrical characteristics.

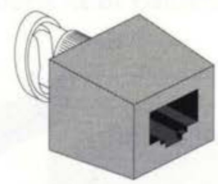


Figure 6.5 A balun for connecting thin and twisted-pair Ethernet

Connecting devices to Ethernet

Transceivers

All devices connect to Ethernet cabling via a *transceiver.* A transceiver electrically isolates a device from the cable, and is responsible for sending and receiving data, as well as detecting collisions – that is when devices try to put data on the cable at the same time. A device may incorporate its own transceiver, or it may require an external transceiver.

Most transceivers have a switch to enable or disable SQE, also called *heartbeat*. If you are using a transceiver to connect a repeater (see R*epeaters* on page 35), it's vital that you can disable heartbeat on that transceiver.

Thick Ethernet

A thick Ethernet transceiver clamps directly onto the cabling, which is inflexible and often relatively inaccessible. Because of this, devices intended for connection to thick Ethernet rarely incorporate a suitable transceiver, but instead provide an AUI *port* to connect to an external transceiver via a cable with an AUI *connector* at each end:

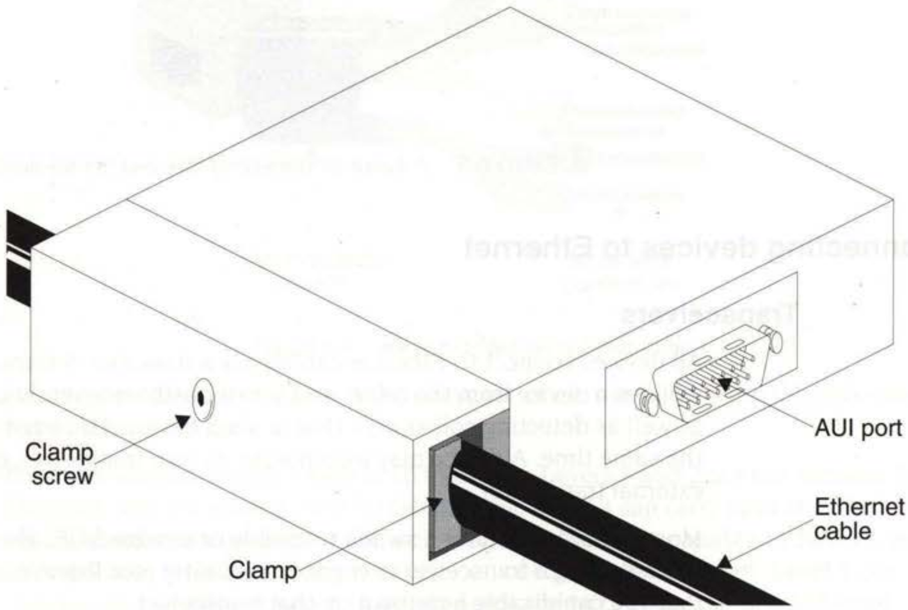


Figure 6.6 A *thick Ethernet transceiver*

The external transceiver is sometimes called a *Media Access Unit*, or MAU.

Thin Ethernet and twisted-pair Ethernet

Thin Ethernet and twisted-pair transceivers use sockets to connect to the cabling, which is flexible and usually accessible. Because of this, it makes much more sense to incorporate the transceiver within a device (or on its network interface card), and many manufacturers choose to do so. Others prefer to provide an AUI port for connection to an external transceiver, either directly or via an AUI cable. An example of this is the A3020/A4000 Access interface. Again, an external transceiver is sometimes called a Media Access Unit.

Connector summary

An AUI port requires an external transceiver; normally an AUI cable is used to connect the two. By using different transceivers, an AUI port can be connected to different types of Ethernet.

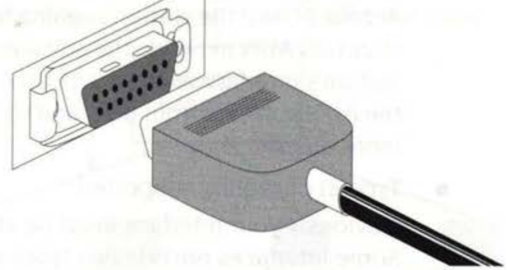


Figure 6.7 An AUI port and cable

A BNC connector is used for direct connection to a thin Ethernet via a T-piece. It does not require an external transceiver.

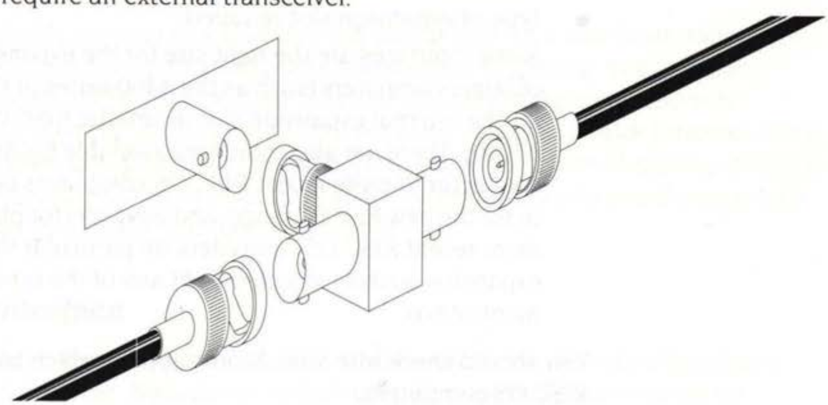


Figure 6.8 A BNC connector, T-piece and cabling

An RJ45 socket (similar to a British domestic phone socket) is used for direct connection to a twisted-pair Ethernet; it also doesn't need an external transceiver.

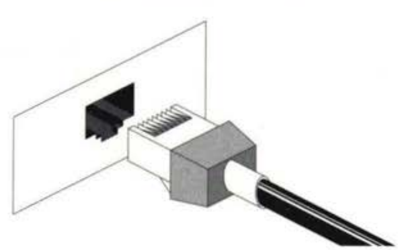


Figure 6.9 An RJ45 socket and lead

Network interfaces

Ethernet interfaces vary in capability, size and cost. Factors to consider are:

- Provision of software in ROM:

  You may prefer or require that your interface has certain networking software supplied in its ROM. For example, a station's network interface **must** have an Access ROM if the station is going to be connected to an Access network. For a standard AUN network, the software doesn't have to be in ROM, but if the station's interface is fitted with an AUN client ROM it saves the station loading the AUN software from disc, and so installation is easier and the station boots more quickly.

- Type(s) of cabling supported:

  Obviously your interface must be able to connect to the cabling you install! Some interfaces provide two types of socket (typically an AUI port and BNC connector), and you can choose which of them you use, giving you flexibility in your choice of cabling. Others may only provide a single socket, to reduce their cost and/or their size.

- Type of expansion slot required:

  Some interfaces are the right size for the expansion sockets on the backplane of larger computers (such as the A400 series or the A5000). Others are suitable for the internal expansion slot in smaller RISC OS computers (such as the A3000). There are also interfaces available for fitting to the network interface connector in more recent RISC OS computers (such as the A3020 and A4000), or for the new Risc PC range, and adaptors for plugging into the parallel port of more recent RISC OS computers (in particular the A4, which does not have the expansion sockets required to fit any of the other types of interface just mentioned).

You should check with your Acorn supplier which types are currently available for RISC OS computers.

Multiport transceivers

A *multiport transceiver* (or *fan-out*) connects multiple devices to the Ethernet via a single transceiver. A typical device would have a single AUI port for connection to a transceiver, and a number of AUI ports to which you can connect workstations.

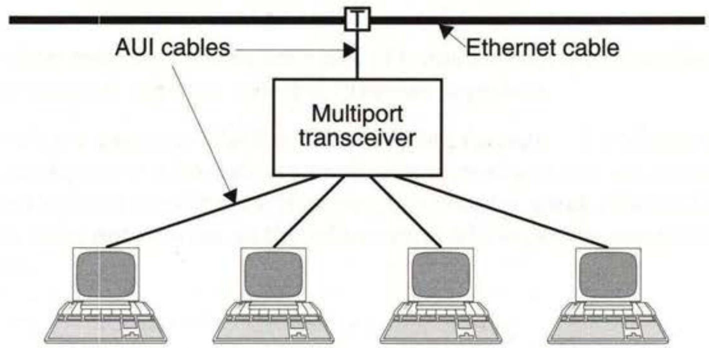


Figure 6.10 A *multiport transceiver*

You can quickly connect new stations to a vacant port on a multiport transceiver, and hence avoid having to attach extra transceivers to cabling. You can also overcome restrictions on how close together you may make connections to cabling. For example, if you were to connect eight stations to thick Ethernet using one transceiver per station, you would need to use at least 20m of cabling, because the connections must be at least 2.5m apart. Alternatively, you could connect all the stations to a single multiport transceiver.

Fibre Distributed Data Interface

Fibre Distributed Data Interface (or FDDI) is a fibre optic network technology that is faster than Ethernet. Because of its high cost, it is currently used mainly for networks that have to carry a large volume of traffic, especially backbones for complex networks. Currently, you cannot connect Acorn computers directly to FDDI.

7 Connecting networks

This chapter describes the various bits of hardware that are most likely to be used to connect together different Ethernet segments.

Together with the previous chapter – *Basic Ethernet hardware* – it will give you the necessary background information to help you understand any recommendations made by dealers and consultants. However, this chapter is **not** a tutorial in network design, and does **not** provide all the information and expertise needed to create a good design.

Repeaters

A *repeater* is the simplest device used to connect together two segments of cable. These can either be thick or thin Ethernet segments to which devices are attached, or special *inter-repeater links* that are used solely to connect two repeaters and the networks to which they are attached. A repeater copies all the bits it receives on each segment to the other one, and has no concept of their meaning. In doing so, it eliminates any degradation that has occurred in the electrical signals on each segment.

Repeaters are commonly used to extend a network beyond the distance where the signal would degrade unacceptably over a single segment.

You can also use a repeater for joining together different types of Ethernet, simply by selecting one with appropriate sockets. For example, a repeater might have a BNC connector for thin Ethernet, and an AUI port which you could connect to thick or thin Ethernet via an appropriate transceiver.

Note that transceivers connected to a repeater must have SQE disabled. (SQE is also known as *heartbeat*.)

Fibre optic repeaters

A *fibre optic repeater* is used to connect a segment of Ethernet to a fibre optic inter-repeater link. It typically has an AUI port for connecting to Ethernet via a transceiver, and an ST connector for connecting to the inter-repeater link. By using two fibre optic repeaters (one at each end of the link) you can connect together two Ethernet segments:

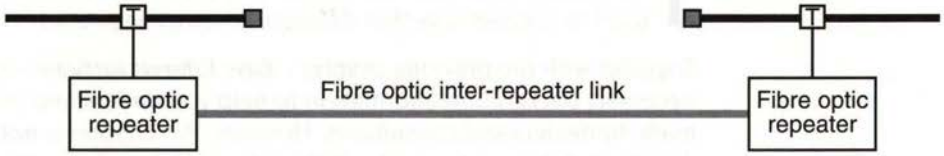


Figure 7.1 Connecting two Ethernet segments with a fibre optic inter-repeater link

If you have to run cabling outside to connect together two networks, we strongly recommend that you use a fibre optic link. This is because:

- It uses light rather than electricity to transmit data, and so is immune to electrical interference from car starter motors, refrigerated lorries, and so on.
- It does not contain metal, and so is safer in the event of a mishap such as a lightning strike.

Multiport repeaters

A *multiport repeater* is similar to an ordinary repeater, except that it has multiple ports, with which it can connect together multiple lengths of cabling:

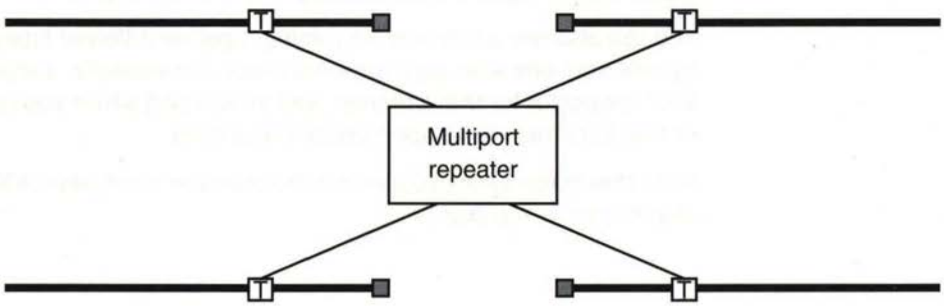


Figure 7.2 A multiport repeater

Hubs

A *hub* is used in a star network to connect together devices. A hub typically has between 8 and 48 RJ45 sockets, each of which can support a single device connected with twisted-pair cabling; and a single socket for connection to a backbone network.

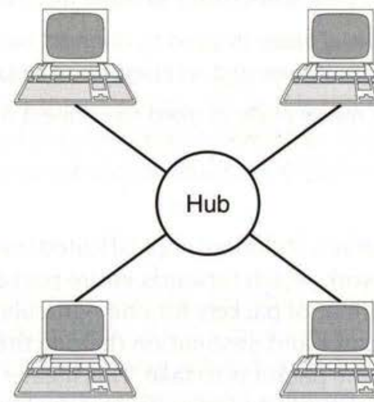


Figure 7.3 A hub with stations connected via twisted-pair Ethernet

Patch panels

A *patch panel* consists of a large number of input and output sockets. Patch panels are often installed between a hub and the devices to which it is connected, and make it much easier to alter the layout of a network.

Bridges

A *bridge* is another device used to connect together segments of cable. It is more sophisticated than a repeater in that it forwards whole frames of data between the two segments. Furthermore, it understands the information in the frames, which includes their source and destination address. The software in a bridge can use and even alter this information to control traffic; better bridges have more flexible and capable software.

A bridge can be configured so that it does not forward local traffic to the rest of the network. Traffic then crosses the bridge only if it needs to do so to reach its destination. Bridges are therefore often used to partition a network, preventing devices on one part of a network from flooding the whole network with signals.

Some bridges support redundant routing, which means you can use multiple bridges to link segments. Software in the bridges disables all but one route between any given pair of segments. If this route fails the software automatically disables it, and enables an alternative route around the break. Hence any extra bridges are not normally used themselves, but just provide backup for those that are in use.

Local and remote bridges

Bridges are sometimes divided into two categories:

- A *local bridge* is used to connect two parts of a local area network. They are sometimes just referred to as *bridges*.
- A *remote bridge* is used to connect a local area network to a wide area network.

Routers

A *router* is a still more sophisticated means of connecting together two segments of a network, which forwards entire packets at a time. A simple router understands the format of packets for one particular protocol; it knows and can alter not only the source and destination (held in the frames making up the packet), but also the route the packet is to take. This means that routers can choose optimum routes for network traffic based on factors such as speed or cost of transmission.

Just as with bridges, you can use multiple routers to link the same segments. Because routers can control exactly where a packet goes, network traffic can be spread between all available routes – unlike bridges, where only one of the routes is in use at a time. Thus any extra routers are used all the time, and not only provide backup for those already present, but also increase the capacity for transferring traffic between segments.

You can also use a router to link together networks that use the same protocol, but that are physically different. For example, you might use a router to connect an Ethernet to a Token Ring.

The simple router outlined above will only forward traffic that uses the single protocol it understands. Obviously such a router is inappropriate for networks that use multiple protocols; in such cases a *bridging router* or a *multiprotocol router* becomes necessary.

Bridging routers

A *bridging router* is one that acts not just as a router for those protocols that it understands, but also as a bridge for packets that use unknown protocols.

Multiprotocol routers

A *multiprotocol router* is one that understands and can route more than one protocol. Incidentally, most multiprotocol routers are also bridging routers – so they can route multiple protocols, and bridge those they don't understand.

Protocol converters

A *protocol converter* is used to join together networks that use different protocols, converting traffic between the protocols. Since it is unlikely that all the features provided by one protocol may be present in another, the protocol converter may inevitably have to make minor compromises in its conversion.

Gateway stations

Bridges, routers and protocol converters are really small computers that are purpose-built for connecting networks. It's therefore no surprise that an ordinary computer can be turned into a *gateway station* that performs one of these functions, simply by adding the necessary hardware and software. Acorn supplies three types of gateway stations: an AUN gateway, a TCP/IP gateway, and a RISC *i*X gateway.

AUN gateways

An AUN gateway is a RISC OS station that is running the Gateway application supplied as a part of Acorn's AUN/Level 4 Fileserver software. It turns the station into both an address server for AUN client stations, and also a router for Internet protocol packets that use AUN's addressing scheme.

Because this scheme only uses a very small subset of all possible Internet addresses, an AUN gateway must not be used in a network that uses the normal TCP/IP addressing scheme.

TCP/IP and RISC *i*X gateways

A TCP/IP gateway is a station running Acorn's TCP/IP Protocol Suite that has been configured to use more than one network interface. Likewise, a RISC *i*X gateway is a standard RISC *i*X station that has been configured to use more than one network interface. Both these types of gateway can be used as a router for Internet protocol packets passing between two networks that use full TCP/IP addressing.

These gateways cannot be used on a network where the client stations are running the standard version of AUN, because neither of them act as an AUN address server; without this, the AUN client stations do not work.

Microwave links

A *microwave link* uses microwaves to pass network traffic between two dish antennae. They are most often used where it is impossible to route a cable between two network segments – for example, where a road needs to be crossed and permission cannot be obtained to dig it up.

Backbone networks

A backbone network is a network segment that is used solely to connect together other network segments, and does not have any workstations connected to itself. Its main purpose is to prevent traffic that is passing between two networks from flooding intervening networks. For example, look at this network that does not use a backbone:

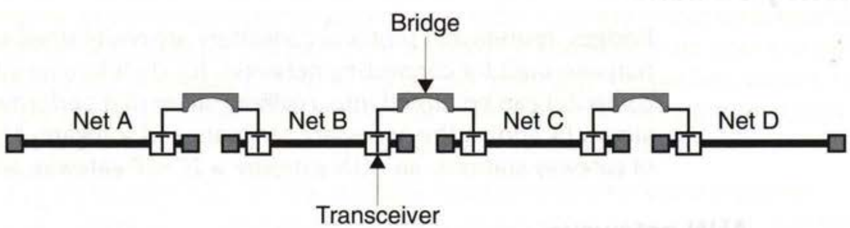


Figure 7.4 A *network without a backbone*

Packets passing between Net A and Net D will cross Nets B and C, possibly overloading them. By adding an extra bridge and backbone network this problem is alleviated:

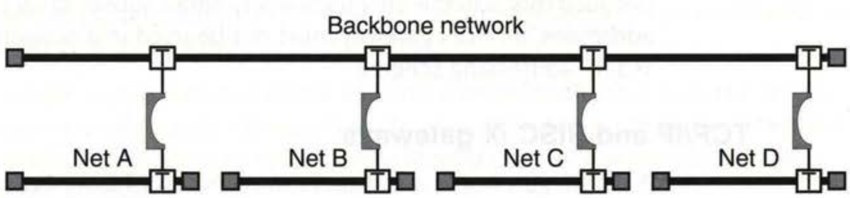


Figure 7.5 A *network with a backbone*

Packets passing between Net A and Net D now pass over the backbone network, and so do not put any extra load on Nets B and C.

Restrictions on the use of repeaters

Repeater counts

There are restrictions on the number of repeaters and/or hubs that can be used consecutively in a network. This is reckoned using a *repeater count*, which corresponds to the number of repeaters and/or hubs that a given packet has crossed:

- When a packet leaves its source, it has a repeater count of zero.
- Each time the packet passes through a repeater or hub, its repeater count is incremented.
- If the packet passes through a device that connects segments at a higher level (e.g. a bridge, router, gateway station or protocol converter), its repeater count is again reset to zero.

The repeater count must not exceed four for any potential route on your network.

Use of segments and inter-repeater links

There are similar restrictions on the counts of Ethernet segments and inter-repeater links that a packet can cross between two higher-order connecting devices. The count of Ethernet segments cannot exceed three, and the count of inter-repeater links cannot exceed two.

Summary

The diagram below illustrates the maximum theoretical use of repeaters on a network:

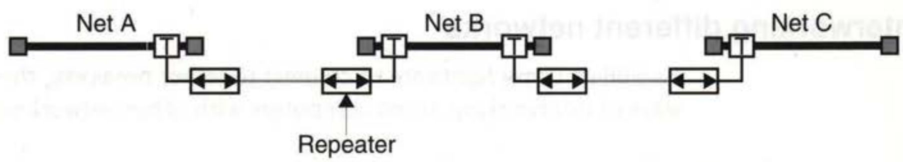


Figure 7.1 Maximum use of repeaters

Traffic passing from Net A to Net C passes over four repeaters, three Ethernet segments, and two inter-repeater links. This network cannot be further extended by using repeaters alone. To do so would require a higher-order connecting device such as a bridge.

If there is any route in your network which would break one or more of the rules given earlier, the network's topology must be altered to correct the flaw. Typically this involves replacing a repeater with a bridge or gateway.

Summary of differences between connecting devices

The table below summarises the differences between the various hardware devices that can be used to connect network segments:

	Repeater	Hub	Bridge	Router	AUN gateway	TCP/IP and RISC *iX* gateway	Protocol converter
Resets repeater, Ethernet segment and inter-repeater link counts	✘	✘	✔	✔	✔	✔	✔
Can partition traffic between segments	✘	✘	✔	✔	✔	✔	✔
Can provide alternative routes between segments	✘	✘	✔	✔	✘	✔	✔
Can spread load between those alternative routes	✘	✘	✘	✔	✘	✔	✘
Can connect different types of Ethernet	✔	✔	✔	✔	✔	✔	✔

Interworking different networks

As well as using hardware to connect together networks, there are various other ways of interworking Acorn computers with other network systems.

Sharing files using an NFS file server

NFS is a widely supported protocol for file access. By adding one or more NFS file servers to a network, files can be shared by any computers that can access NFS.

Acorn's own RISC *iX* computers can act as NFS file servers, and can also access any other NFS file servers. RISC OS computers cannot themselves act as NFS file servers, but can access NFS file servers using the NFSFiler application, which is available as a part of Acorn's TCP/IP Protocol Suite.

Solutions are available for many other manufacturer's machines; these may involve hardware and/or software. For example, PC-NFS software allows PC-compatibles to access an NFS file server; a GatorBox allows an Apple Macintosh to do likewise.

Novell access using PC Soft

Acorn computers can run the PC Soft software to emulate a PC-compatible computer. The computer can then run Novell client networking software, and hence connect to a Novell network as a client. However, the computer cannot act as a Novell server.

Novell access using a PC card

Acorn computers can instead be fitted with a PC card or, in the case of the Risc PC, with a 486 second processor. This allows the computer to act as a PC-compatible computer, and to make full use of Novell networking software; hence an Acorn computer can have full connectivity to a Novell network.

Novell access using software

At some time in the future, software may become available for connecting standard Acorn computers directly to a Novell network. If you need such a product, ask your supplier about its availability.

Glossary

This glossary defines any new terms that you may have come across in this Guide – mostly those that are that are specific to Ethernet networking. Terms in italics have their own definition in this glossary.

Access — an entry-level AUN network that is designed for simple installation and easy use.

AUI port — a port used to connect a device to a *transceiver*, usually via an AUI *cable*.

AUI cable — a cable typically used to connect a device to a *transceiver*.

AUN — Acorn Universal Networking, Acorn's networking strategy.

backbone network — a network the purpose of which is to carry traffic directly from one network on a site to another.

balun — a small connector incorporating a transformer, used to connect dissimilar types of *Ethernet* cabling.

BNC connector — a type of connector used to connect a device to *thin Ethernet* cabling via a *T-piece*.

bridge — a hardware device used to link together two parts of a physical network of the same type (e.g. *Ethernet*) and to filter out data not destined for either part.

bridging router — a *router* that can act as a *bridge* for those *protocols* it does not understand.

bus topology — a network that is layed out in a line, with each *station* connected to a continuous piece of wire that has no loops.

Cheapernet — an alternative name for *thin Ethernet*.

client-server network — a network where server *stations* provide services, and client *stations* use those services.

coaxial cable — cable with a shield around a central conducting core, used in different forms for *thick* and *thin Ethernet*.

Econet — Acorn's own low cost networking system.

Ethernet — an industry standard networking system offering a greater bandwidth than *Econet*, but at a higher cost.

fan-out — an alternative name for a *multiport transceiver*.

FDDI — Fibre Distributed Data Interface, a fibre-optic network technology.

fibre optic repeater — a device used to connect a segment of *Ethernet* to a fibre optic *inter-repeater link*.

file server — a *station* on which other *stations* can store and retrieve files.

gateway station — a *station* connected to two networks, and used to pass data between them.

GatorBox — a hardware device that allows Apple Macintoshes to access NFS file servers.

heartbeat — an alternative name for SQE.

hub — a piece of *Ethernet* hardware used to connect together *twisted-pair Ethernet* cabling from a number of *stations*.

Internet — a family of *protocols* that have become an industry standard.

inter-repeater link — a length of cabling used to connect together two *repeaters*.

IP — an abbreviation for the industry standard *Internet protocol*.

LAN — an abbreviation for a *local area network*.

Level 4 Fileserver — Acorn software that turns an ordinary *station* into a *file server* without the need for specialised hardware.

local area network — a network covering a small area such as a single site.

microwave link — a link that uses microwaves to pass network traffic between two dish antennae, often used where it is impossible to lay cable.

multiport repeater — a *repeater* that provides a number of identical outputs.

multiport transceiver — a box that can connect multiple devices to the Ethernet via a single *transceiver*.

multiprotocol router — a *router* that can understand multiple *protocols*.

network interface — a hardware device used to connect a computer to a network, typically produced as a plug in circuit board or as an expansion card.

NFS — the Network File System, provided as a part of the TCP/IP *Protocol Suite*, used to access files on other machines running NFS (such as UNIX workstations).

Novell NetWare — software commonly used to network PC-compatibles.

patch panel — a panel with a large number of input and output sockets, used to alter the layout of a network quickly and easily.

PC-NFS — software that allows PC-compatibles to access NFS file servers.

peer-to-peer network — a network where all *stations* have equal status, and can provide or use services.

print server — a *station* to which other *stations* can send output for printing.

protocol — the way in which data is sent over a network.

protocol converter — a hardware device used to link together networks that use different *protocols* by converting between the two.

redundant routing — the provision of multiple routes between networks where only one route is required.

remote bridge — a *bridge* used to connect a *local area network* to a *wide area network*.

repeater — a hardware device used to extend the distance a network can cover by restoring the strength and quality of signals.

repeater count — a count of the number of *repeaters* network traffic has passed through, without passing through other higher level devices such as a *bridge*.

ring topology — a network that is layed out in a ring shape, with each *station* connected to a ring of wire; this is not available for Acorn computers.

riser — a vertical section of cabling used to connect networks on separate floors, and typically connected to them by *bridges* or *repeaters*.

RJ45 connector — a type of connector used for *twisted pair* Ethernet cabling.

router — a hardware device used to link together two segments of a network and control the routing of traffic over the network.

SQE — a signal that is provided by a *transceiver*, and is usually switchable.

star topology — a network that is layed out in a star shape, with each *station* connected to a central *hub*.

station — a computer connected to a network.

ST connector — a type of connector used with fibre optic cables.

TCP/IP — an abbreviation for Transmission Control Protocol / Internet Protocol, an industry standard used in particular by UNIX computers.

TCP/IP Protocol Suite — an Acorn product providing a wide range of facilities to RISC OS *stations* connected to a TCP/IP configured network.

terminator — a resistor connected to each end of a *bus network* to preserve the quality of electrical signals.

thick Ethernet — a variety of E*thernet* cabling able to support more *stations* over a longer cable run than *thin* E*thernet*, but in a less convenient and more expensive form.

thin Ethernet — a variety of *Ethernet* cabling able to support fewer *stations* over a shorter cable run than *thick Ethernet*, but in a more convenient and less expensive form.

Token Ring — a type of network that uses a *ring topology*, and that uses different *protocols* to Ethernet.

T-piece — a T-shaped connector normally used to connect two *thin Ethernet* cables to a BNC *connector*.

transceiver — a piece of hardware used to connect a device to *Ethernet* cabling, (often integrated within the device).

twisted-pair Ethernet — a variety of *Ethernet* cabling that is inexpensive, and used to connect a single *station* to a *hub*.

UNIX — a widely used operating system.

unshielded twisted-pair cable — a cable made up of pairs of insulated conductors twisted around each other.

UTP — an abbreviation for unshielded twisted-pair.

WAN — an abbreviation for a *wide area network*.

wide area network — a network covering a large area such as a town, country or continent.

Index

U

V

W

Reader's Comment Form

Ethernet Design and Installation Guide

We would greatly appreciate your comments about this Guide, which will be taken into account for the next issue:

Did you find the information you wanted?

Do you like the way the information is presented?

General comments:

If there is not enough room for your comments, please continue overleaf

How would you classify your experience with computers?

☐ **First-time user** ☐ **Used computers before** ☐ **Experienced User** ☐ **Programmer**

Cut out (or photocopy) and post to:
Dept RC, Technical Publications
Acorn Computers Limited
Acorn House, Vision Park
Histon, Cambridge CB4 4AE
England

Your name and address:

This information will only be used to get in touch with you in case we wish to explore your comments further

Acorn

AED 24