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A Fresh Look at the Provision of Bandwidth to a Health Agency

James G. Leahy
Department of Mathematics and Computers, Cork Institute of Technology, Cork, Ireland.

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A Fresh Look at the Provision of Bandwidth to a Health Agency

James C. Leahy
A Fresh Look at the Provision of Bandwidth to a Health Agency

By

James G Leahy

Cork Institute of Technology

A thesis submitted to fulfil the requirement for the degree

Of

Master of Computer Science

Department of Mathematics and Computers
Cork Institute of Technology

2001
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To my parents and family who have been supportive and understanding, while I was working on this project.
Abstract

This thesis describes development of a networking infrastructure to support a Regional Health Service in Ireland. It covers:-

- The design, building, commissioning and delivery of a Forward Emergency Control Vehicle to provide the video, voice and data communications needed to enhance delivery of patient care in Disaster Situations. The main focus here is on the integration of satellite and terrestrial communications.

- By studying the history of telecommunications provision over copper, the best use is made of the legacy copper cabling in and between existing buildings on a campus to provide both voice and data services.

- A financial tool is developed to ensure optimal purchase of bandwidth from Telecoms providers for inter-campus communications.

- Where copper on the campus, or the Telecom Operators offerings between campi do not provide us with an optimal solution, then the provision of communications over wireless systems is examined. Several wireless solutions and implementations are presented.
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1. Introduction

1.1. Company Description (Southern Health Board)

The Southern Health Board’s area of healthcare responsibility is the South West Region of Ireland incorporating the counties of Cork and Kerry. It is perhaps the most varied of areas in Ireland encompassing populous urban areas such as Cork City with approximately 250,000 citizens, and also some towns having population of 5,000 to 15,000, small rural villages and also some islands having residents, of between 50 and 300 people.

The provision of Acute Hospital care in the region is based at two primary centres, Cork University Hospital, a high-tech Class One Trauma Centre and Tralee General Hospital where there are Regional Specialist Services. These are supported by two smaller General Hospitals at Bantry and Mallow. There is also a network of 21 Community Hospitals, which provide locally based health support services to the community. In all there are more than 220 locations within the Board’s control.

The Accident and Emergency (A&E) Departments at the hospitals deal with accident and emergencies with patients being transferred by air or land ambulance services. In more remote locations initial assistance is given to the patient by locally based General Practitioners [GPs] or Public Health Nurses [PHNs].

In addition to the challenges presented by the geography and infrastructure of the region there are a number of major contributing factors that emphasize the need to provide facilities to manage possible major accidents and emergencies. The region is a major tourist area for Ireland. This raises the population by 50% in the high season with a consequence increase in traffic particularly in some mountainous
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areas. These roads by their nature are narrow and with the increased traffic so does the number of crashes. The region also holds a number of major events including significant ‘on street’ activity for example the internationally famous Rose of Tralee festival.

Figure 1-1  The Southern Health Board Area of Care

The Cork area is host to many of the world’s large pharmaceutical manufacturers, these are concentrated in one location. Ireland’s main petroleum storage facility is based near Bantry, in the South West of the region. The coastline is on the main transatlantic air route. The deep-water port of Castletownbere is the main staging point for a number of international fishing fleets. Finally the rugged coastline is used to stage many sea races and activities.
Unfortunately, over the years, the area has experienced a number of major accidents and disasters. These incidents have spanned the areas as seen in figure 1-1 and listed below:

- The Air India disaster – crash of Air India jumbo jet off the South West Coast
- Whiddy Oil Terminal disaster – explosion and destruction of petroleum landing and storage area.
- Buttevant Train crash
- Fire and explosion in a pharmaceutical plant

The ability to expand and co-ordinate major accidents and disasters have long been regarded as a priority by the Board’s activities. The Board has been the driving force in the creation of a Major Accident Plan in conjunction with the other major accident emergency service.

The Board’s area of responsibility is divided into five administrative:

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Table 1-1 **Southern Health Boards Administrative areas**
The Health Boards Headquarters are at Aras Slainte. The primary service centres consists of two Maternity hospital (Erinville and St Finbarrs in Cork City ) the four Acute hospitals mentioned above and three psychiatric hospitals (Our Ladys Cork City, St Stephans Glanmire and St Finnians Killarney) are the main sites. The remaining sites are Community Hospitals and Health Centres. These are also used used for clinics and as bases for mobile workers such as Public Health Nurses (PHN’s) and Environment Health Officers (EHO’s). Some of the sites were built as Tuberculosis (TB) Hospitals; which were designed as multi-building campi (to minimise the spread of disease from one building to another). The present communication infrastructure has all these buildings cabled for phone services using copper from a central phone system PABX. One of the challenges facing the Southern Health board is to network all these buildings even though some buildings may have only one or two users. Other buildings are large having three to four foot thick walls and with groups of users on different floors or in areas 50 meters apart.

1.2. Emergency Response Development

The Vehicle was designed to take cognisance of the Southern Health Board’s extensive experience of major emergency and disaster management. Vehicles currently available are mostly designed for military use and are therefore, too expensive, too large and too sophisticated for most healthcare and other relevant organisations.

The design of an emergency response vehicle will draw on this expertise and the development shall combine an optimum level of technological sophistication with low cost. The Vehicle should also integrate terrestrial and satellite
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communications. This combination enables the establishment of communications immediately upon arrival on-site, if the terrestrial infrastructure is intact and even before Satellite Communications can be established. Thus, maximum advantage is taken of the Golden Hour (the first hour after an accident which is the time where the largest impact can be made).

The concept of the Forward Emergency Control Vehicle (FECV) is that of a mobile-mounted integrated terrestrial and satellite communications system. The FECV will be capable of being driven or airlifted to the site of any disaster or major emergency. This will significantly aid the efficient medical and general management of any such situation.

Consequently, the objectives of the project are to:

Design a cost effective, ergonomically operational structure
Build a robust vehicle to the above design
Integrate Technologies as much as possible from those in common use within the Board up to the most advanced Satellite Communications
Commission the resulting system
Provide training material for users
Have a vehicle that can integrate into Ambulance Services in its day-to-day activities
1.3. The re-use of existing infrastructure

As mentioned previously, the Southern Health Board has a lot of copper wires in the ground both between buildings and within them. In order to use efficiently this copper, an understanding of the rationale, underpinning the design of copper cables will be explored. This will then be used to design and build campus networks that will provide the features required in a cost effective manner. Once these campus level networks the decision then is how best to link all these sites in a corporate Wide Area Network (WAN) in the most cost effective way.

The objectives of this section are:

The theory of copper use

The problems and solution of these problems in the past

The use of this information to deliver solutions to the Board

Modelling the pricing of different WAN options.

2. Satellite

This chapter gives an understanding of satellite communications, the different types of satellites the different frequency, and the benefits of each. The fact that all satellites are at a distance from the earth places a fixed delay when communicating between any two points on the earth, this may cause problems. The latter part of the chapter deals with the calculation regarding link budget, system power needs depending on the bandwidth and dish size used.
2.1. Satellite Description

Satellites can be positioned in orbits at different heights and shapes (circular or elliptical). Based on the orbital radius, all satellites fall into one of the following three categories.

- **LEO:** Low Earth Orbit.
- **MEO:** Medium Earth Orbit.
- **GEO:** Geostationary Earth Orbit.

From a point of commercial availability and coverage, GEO systems are more cost effective and give coverage in the area supported by the Southern Health Board.

As well as three types of positioning, there are three frequency bands, namely C, Ku, and Ka Bands. C and Ku Bands are the most common frequency spectrums used by today's commercial satellites. These are part of the radio spectrum known as the Super High Frequency (SHF), band that extends from 3GHz to 30GHz. This Band is sometimes called the centimetre band, as the wavelength of SHF ranges from 1 to 10 cm.

As wavelength increases, frequency decreases, and as wavelength increases, larger antennas are necessary to gather the signal. With this in mind C Band satellite transmissions occupy the 4 to 8 GHz frequency range. C Band wavelengths require a larger satellite antenna to gather the minimum signal strength. The size of a C Band antenna is usually 3 meters in diameter or larger.

Ku Band satellite transmissions occupy the 11 to 17 GHz frequency range. These relatively high frequency transmissions correspond to shorter wavelengths and,
therefore, a smaller antenna can be used to receive the minimum signal strength. KU Band antennas can be as small as 0.6 meters in diameter.

Ka Band satellite transmissions occupy the 20 to 30 GHz frequency range. Therefore these are very high frequency transmissions and require very small diameter antennas, but the equipment is expensive.

The preferred option here is to use the Ku Band system as the remote dish has to be easily transported and the system has to be cost effective. A future solution may be the use of, Ku receive and Ka transmit at the remote site. This would allow for a very small dish, giving a good response.

2.2. **Characteristics of a satellite system**

The propagation time for a signal to travel up to a geosynchronous satellite and back down to earth is around a quarter of a second. This means a half second (500ms) will elapse before a sender receives a return message. Some protocols designed for terrestrial networks will time out before this, under the assumption that such a time delay indicates congestion of the network. This is an important consideration when working with Internet Protocol (IP) and even more delay dependant application such as Voice Over Internet Protocol (VOIP).

The received microwave power involved in satellite links is typically very small (of the order of a few 100 picowatts). This means that specially designed stations that keep the carrier to noise (C/N) ratio to a maximum, are used to transmit/receive satellite communications. The front-end receiver is the most crucial part of the transceiver and is a major factor in the overall cost of the satellite station. It
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typically employs a large antenna (the gain of a parabolic antenna is proportional to the square of its diameter) and a highly linear, low noise amplifier (LNA).

The down link from the satellite can have a large footprint providing coverage for a substantial area, or a "spot beam" can be used to focus high power on a small region. The contours of the footprint give the expected power in dBW for that location. It is actually an aggregation of multiple beams, normally elliptically shaped, and individually steerable.

For this specific coverage area, the aggregated EIRP (effective isotropic radiated power), antenna gain to noise temperature (G/T), and input flux density contours are generated by multiple elliptical beams, which often overlap.

The ground station used is a Very Small Aperture Terminal (VSAT) consisting of an outdoor unit (ODU) and a small parabolic antenna (less than 2 meters) which is connected to an indoor unit (IDU) by coaxial cable. The IDU can be described as a satellite modem. The term 'Very Small' here is in reference to satellite dish which relation to those earth station's normally in use for general telephony is indeed very small. The first large earth station in Ireland was installed in Elfordstown, Middleton, County Cork in 1984, and has a dish size of 32 meters. VSAT's are usually perceived to be two-way data terminals, though many are used for data broadcast only. European Telecommunications Standards Institute (ETSI) defines a VSAT as a one or two way terminal used in a star, mesh or point-to-point network, where the antenna size is less than 3.8 meters in diameter. VSAT networks work best if either the transmitter or the receiver antenna is larger, in fact some transmit stations can be up to 9 meters in diameter.
In order to simplify VSAT design, a lower performance microwave transceiver and lower gain dish antenna, small size is used where they act as bi-directional earth stations. These are small, simple and cheap enough to be installed in the end user's premises. VSAT networks are typically arranged in a star based topology, where each remote user is supported by a VSAT. The central hub station acts as the central node and employs a large size dish antenna with a high quality transceiver. The satellite provides a broadcast medium acting as a common connection point for all the remote VSAT earth stations. VSAT networks are ideal for centralized networks with a central host and a number of geographically dispersed terminals.

2.3. Satellite Link Budget

A ‘Link Budget’ is a generic term used to describe a series of mathematical calculations designed to model the performance of a communications link. The following data is needed to produce a link budget calculation for a satellite to ground station link.

- Earth Station Latitude.
- Earth Station Longitude.
- Spacecraft Longitude.
- Downlink Frequency.
- Antenna Gain.
- Antenna Noise Temperature.
- Low Noise Amplifier (LNA) Gain.
- Low Noise Block Converter (LNB) Noise Figure.
- Ortho Mode Transfer (OMT) Loss.
- Effective isotropic radiated power (EIRP).
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- Transmit Data Rate.
- Link Rain Margin.

The following is a list of symbols and their meanings that are relevant to satellite communication.

Pfd  The Power flux density (power received / unit area)
Ps   Transmit power in watts
Gs   Gain of the Dish
$4\pi D^2$ Surface area of a Sphere with radius D
EIRP effective isotropic radiated power
$(PsGs) = [10 \log (Gs) + 10 \log (Ps)] \text{ dBW}$
$Pfd = \text{EIRP} - 10 \log (4\pi D^2) \text{ dBW/m}^2$
C The carrier power received
Path loss $20 \log (4\pi D/\lambda)$
Gd Gain of receive dish
$C = Ps(dB) + Gs(dB) + Gd(dB) - 20 \log (4\pi D/\lambda)$
$\frac{1}{2}$ rate FEC for every 1 bit of data 2 bits are transmitted to allow for Forward Error Correction.
BER Bit Error Rate a BER $10^{-3}$ refers to the probability of 1 error in 1000 bits transmitted.
T Temperature in degrees Kelvin
N Noise in dB
$3\text{dB}$ atmosphere attenuation
$Eb/No = \text{Energy per bit versus the noise in the signal's bandwidth}$
Forward error correction puts a high overhead on the transmission of data, and as bit error rate decreases this overhead becomes overkill. The main problem with the time delay on a satellite link is retransmission if this is required.

<table>
<thead>
<tr>
<th>Average bit rate</th>
<th>64Kbits</th>
<th>256Kbits</th>
<th>1.5Mbits</th>
<th>10Mbits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BER 1.00E-06</td>
<td>16 sec</td>
<td>3.9 sec</td>
<td>0.7 sec</td>
<td>0.1 sec</td>
</tr>
<tr>
<td>BER 1.00E-09</td>
<td>4.3 hours</td>
<td>65 min</td>
<td>11 min</td>
<td>1.7 min</td>
</tr>
<tr>
<td>BER 1.00E-12</td>
<td>6 months</td>
<td>1.5 months</td>
<td>7.7 days</td>
<td>1.2 days</td>
</tr>
</tbody>
</table>

Table 2-1 Average time interval between consecutive bit errors

(from de Prycher, M, Asynchronous Transfer Mode Solution for Broadband ISDN,...pp243,...)

2.4. Calculating Power needs for systems

In calculating the link budgets, the model designed by Eutelsat will be employed (Guidelines for the determination of the space segment capacity to be allocated for digital carriers on Eutelsat w/ sesat, 72Mhz, 12Ghz transponders ). The first form allows the Transmitted Symbol Rate to be determined as follows:
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**Determination of Transmitted Symbol Rate**

Please fill in the following fields:

- Information bit rate including overhead or framing if any:
- Channel Forward Error Correction rate (FEC), 1/2, 3/4, ... 1 if no FEC
- Reed Solomon coding (RS), 204/188, 219/201, ... 1 if no RS

Select from the list the modulation type (PSK, FSK or MSK)

Select from the list the number of phase/frequency (M)

For Spread Spectrum technique enter the spreading factor (or 1 if no):

<table>
<thead>
<tr>
<th>Efficiency</th>
<th>Spectral efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 bit/symbol</td>
<td>2.000 Mbit/s Hz</td>
</tr>
</tbody>
</table>

Transmitted Symbol Rate

| TSR | 0.054 Mbauds |

Table 2-2  **TSR calculations**

The next form calculates the C/No for the bandwidth required. In this example 56 Kbs
Determination of the C/No+10 required under clear sky condition (C/No\textsubscript{req})

Information bit rate including overhead or framing if any

Channel forward error correction rate (FEC): 1/2, 3/4, ... if no FEC

Use of the EUTELSAT's assumptions for Bit Error Rate and availability (Y/N)

If yes:
- Please select from the list the required Bit Error Rate
  - Corresponding Eb/No - Note 1
- Please fill in:
  - the required Availability (%) - Note 2
  - corresponding period: year (Y) / the worst month (M)
  - Corresponding rain margin

If no: please fill in the following fields:

- Required Eb/No at threshold of the receiver
  - 4.70 dB
- Required rain margin
  - 1.20 dB

Required Eb/No under clear sky condition (Eb/No\textsubscript{c})

Required C/No+10 under clear sky condition (C/No\textsubscript{req})

Note 1: The calculated values of Eb/No are valuable for carriers without Reed Solomon coding.

Note 2: Required availability between 99.0 and 99.9% of the year and between 99.0 and 99.9% of the worst month.

<table>
<thead>
<tr>
<th>Eb/No</th>
<th>10E-1</th>
<th>10E-2</th>
<th>10E-3</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.2</td>
<td>4.7</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>4.3</td>
<td>4.7</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>4.4</td>
<td>4.7</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>4.5</td>
<td>4.7</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>4.6</td>
<td>4.7</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>4.7</td>
<td>4.7</td>
<td>6.2</td>
<td></td>
</tr>
<tr>
<td>4.8</td>
<td>4.7</td>
<td>6.2</td>
<td></td>
</tr>
</tbody>
</table>

EUTELSAT's BER standard values

<table>
<thead>
<tr>
<th>BER</th>
<th>IF Eb/No</th>
<th>I\textsubscript{FEC} 1/2</th>
<th>IF Eb/No</th>
<th>I\textsubscript{FEC} 3/4</th>
</tr>
</thead>
<tbody>
<tr>
<td>10E-2</td>
<td>4.2</td>
<td>5.3</td>
<td>4.7</td>
<td>6.2</td>
</tr>
<tr>
<td>10E-3</td>
<td>4.7</td>
<td>6.2</td>
<td>4.7</td>
<td>6.2</td>
</tr>
<tr>
<td>10E-4</td>
<td>5.4</td>
<td>7.0</td>
<td>5.4</td>
<td>7.0</td>
</tr>
<tr>
<td>10E-5</td>
<td>6.1</td>
<td>7.6</td>
<td>6.1</td>
<td>7.6</td>
</tr>
<tr>
<td>10E-6</td>
<td>6.7</td>
<td>8.3</td>
<td>6.7</td>
<td>8.3</td>
</tr>
<tr>
<td>10E-7</td>
<td>7.3</td>
<td>9.0</td>
<td>7.3</td>
<td>9.0</td>
</tr>
</tbody>
</table>

Table 2-3 Determination of the C/No

The values already calculated are then added to the main form by Macros and the remaining values can be set to default values if different from the those already inputted. As the file is a spreadsheet once the cell has been changed and the cell is exited then the change is reflected on all dependant cells.
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Space Segment Resources and Associated Number of Units of Space Segment utilization for a single carrier

<table>
<thead>
<tr>
<th>Input Parameters</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1) Carrier characteristics:</strong></td>
</tr>
<tr>
<td>Transmitted Symbol Rate</td>
</tr>
<tr>
<td>Requested bandwidth</td>
</tr>
<tr>
<td>Allocated bandwidth</td>
</tr>
</tbody>
</table>
| Required C/No+Io under clear sky condition (C/No,
| C/No entered | C/No | 54.89 dBHz |

| **2) Receive earth station characteristics:** |
| Clear sky G/T (at 12.5 GHz) in the direction of the satellite |
| (G/T)_{12.5} | 25.5 dB/K |
| Cross-Polar Discrimination in the direction of the satellite (Default value = 35.0 dB) |
| CPD_{x} | 35.0 dB |
| Antenna off-axis gain, co-polar component (Default value = 29.0 dBi) |
| Y | 29.0 dBi |
| Antenna off-axis gain, cross-polar component (Default value = 19.0 dBi) |
| X | 19.0 dBi |
| Receive antenna gain (at 12.5 GHz) in the direction of the satellite |
| (Default value = G/T_{12.5} + 22.5) |
| G_{x} | 48.0 dBi |

<table>
<thead>
<tr>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum carrier IPFD from where the satellite G/T is 0.0 dB/K</td>
</tr>
<tr>
<td>IPFD_{x}</td>
</tr>
<tr>
<td>Maximum required EIRP from where the satellite G/T is 0.0 dB/K *</td>
</tr>
<tr>
<td>EIRP_{x}</td>
</tr>
<tr>
<td>Transponder Power Resource</td>
</tr>
<tr>
<td>TPR</td>
</tr>
<tr>
<td>Space Segment Resource</td>
</tr>
<tr>
<td>SSR</td>
</tr>
<tr>
<td>Associated Number of Units of Space Segment Utilisation</td>
</tr>
<tr>
<td>Nunits</td>
</tr>
<tr>
<td>Associated Credit of Allotted Bandwidth with Respect to Power</td>
</tr>
<tr>
<td>Cb</td>
</tr>
</tbody>
</table>

* *Satellite elevation angle θ as seen from the transmit station* |
| θ | 28.7 |

**Table 2-4 Main calculator for EIRP required**

The tables shows the gain at 12.5 GHz which are the figures given by Eutelsat are for a frequency of 14.25 GHz. The gain for 1.2-meter dish using this frequency (14.25 GHz the transmit frequency) is 43.2 dBi.
2.4.1. Calculations for 56Kps circuit

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circuit bandwidth required</td>
<td>56Kbit/s</td>
</tr>
<tr>
<td>Overheads</td>
<td>No</td>
</tr>
<tr>
<td>FEC</td>
<td>$\frac{1}{2}$</td>
</tr>
<tr>
<td>Modulation type</td>
<td>QPSK</td>
</tr>
<tr>
<td>Transmit Symbol rate</td>
<td>56 Kbauds</td>
</tr>
<tr>
<td>Eb/No</td>
<td>6.1dB for a BER of 1E-6</td>
</tr>
<tr>
<td>R.M</td>
<td>1.3dBi</td>
</tr>
<tr>
<td>C/No clear sky</td>
<td>54.89dBz</td>
</tr>
</tbody>
</table>

1.2-meter dish parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G/T</td>
<td>19.5dBK</td>
</tr>
<tr>
<td>Xpol</td>
<td>35dBi</td>
</tr>
<tr>
<td>SSR</td>
<td>0.40%</td>
</tr>
<tr>
<td>Maximum EIRP required at 0dBK contour</td>
<td>54dBw</td>
</tr>
<tr>
<td>RX gain at 12.5GHz</td>
<td>42dBi</td>
</tr>
<tr>
<td>TX gain at 14.25GHz</td>
<td>43.2dBi</td>
</tr>
</tbody>
</table>

1.8-meter dish parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G/T</td>
<td>23dBK</td>
</tr>
<tr>
<td>Xpol</td>
<td>35dBi</td>
</tr>
<tr>
<td>SSR</td>
<td>0.22%</td>
</tr>
<tr>
<td>Maximum EIRP required at 0dBK contour</td>
<td>51.7dBw</td>
</tr>
<tr>
<td>RX gain at 12.5GHz</td>
<td>45.5dBi</td>
</tr>
<tr>
<td>TX gain at 14.25GHz</td>
<td>46.7dBi</td>
</tr>
</tbody>
</table>

2.4-meter dish parameters

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>G/T</td>
<td>25.5dBK</td>
</tr>
<tr>
<td>Xpol</td>
<td>35dBi</td>
</tr>
<tr>
<td>SSR</td>
<td>0.15%</td>
</tr>
<tr>
<td>Maximum EIRP required at 0dBK contour</td>
<td>50.6dBw</td>
</tr>
<tr>
<td>RX gain at 12.5GHz</td>
<td>48dBi</td>
</tr>
<tr>
<td>TX gain at 14.25GHz</td>
<td>49.2dBi</td>
</tr>
</tbody>
</table>

Table 2-5 Using 56Kbps circuit
From map in Figure 2-1 the geographical advantage on EIRP required to cover all of the Southern health boards coverage is +4dB. The transmit coverage is calculated as the advantage over the 45dB contour. The Boards area is divided by the 48dB contour. With West Cork and West Kerry lying in the 47dB coverage. This gives an advantage of typically 2 and 3 dB, and for ease of calculations +3dB will be used.

This will cancel out the High Power Amplifier HPA backoff of 3dB, allowed so as not to saturate the HPA. This is more important as the size of the dish increases and also as the power of the HPA increases.
Calculating Transmit Power requirements

A 1.8-meter dish in Cork

Maximum EIRP required at 0dBK contour 51.7dBw
Adjustment for protected bandwidth 2.0dB
Geographical advantage 4.0dB

EIRP needed 45.7dBw

A 1.2-meter dish as remote

RX gain at 12.5GHz 42dBi
TX gain at 14.25GHz 43.2dBi

Output backoff HPA 3dB
Geographical advantage 3dB

Differences
12.5GHz 3.7dB Power 2.3 W
14.25GHz 2.5dB Power 1.77W

A 1.2-meter dish in Cork

Maximum EIRP required at 0dBK contour 54dBw
Adjustment for protected bandwidth 2.0dB
Geographical advantage 4.0dB

EIRP needed 48dBw

A 1.8-meter dish as remote

RX gain at 12.5GHz 45.5dBi
TX gain at 14.25GHz 46.7dBi

Output backoff HPA 3dB
Geographical advantage 3dB

Differences
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<table>
<thead>
<tr>
<th>Frequency</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5GHz</td>
<td>2.5dB</td>
</tr>
<tr>
<td>14.25GHz</td>
<td>1.3dB</td>
</tr>
</tbody>
</table>

**Table 2-6 Power requirements at 56Kbps**

From the above calculations it can be seen that a 56Kbps circuit is obtainable with a 2W transmitter.

### 2.4.2. Calculations for a Bandwidth of 128Kbps

<table>
<thead>
<tr>
<th>Circuit bandwidth required</th>
<th>128Kbit/s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overheads</td>
<td>No</td>
</tr>
<tr>
<td>FEC</td>
<td>½</td>
</tr>
<tr>
<td>Modulation type</td>
<td>QPSK</td>
</tr>
<tr>
<td>Transmit Symbol rate</td>
<td>128 Kbauds</td>
</tr>
<tr>
<td>Eb/No</td>
<td>6.1dB for a BER of 1E-6</td>
</tr>
<tr>
<td>R.M</td>
<td>1.3dB</td>
</tr>
<tr>
<td>C/No clear sky</td>
<td>58.48dBi</td>
</tr>
</tbody>
</table>

**1.2-meter dish parameters**

<table>
<thead>
<tr>
<th>G/T</th>
<th>19.5dBK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xpol</td>
<td>35dB</td>
</tr>
<tr>
<td>SSR</td>
<td>0.76%</td>
</tr>
<tr>
<td>Maximum EIRP required at 0dBK contour</td>
<td>56.8dBw</td>
</tr>
<tr>
<td>RX gain at 12.5GHz</td>
<td>42dBi</td>
</tr>
<tr>
<td>TX gain at 14.25GHz</td>
<td>43.2dBi</td>
</tr>
</tbody>
</table>

**1.8-meter dish parameters**

<table>
<thead>
<tr>
<th>G/T</th>
<th>23dBK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Xpol</td>
<td>35dB</td>
</tr>
<tr>
<td>SSR</td>
<td>0.42%</td>
</tr>
<tr>
<td>Maximum EIRP required at 0dBK contour</td>
<td>54.8dBw</td>
</tr>
<tr>
<td>RX gain at 12.5GHz</td>
<td>45.5dBi</td>
</tr>
<tr>
<td>TX gain at 14.25GHz</td>
<td>46.7dBi</td>
</tr>
</tbody>
</table>

**2.4-meter dish parameters**
Calculating Transmit Power requirements

A 2.4-meter dish in Cork

Maximum EIRP required at 0dBK contour 53.4dBw
Adjustment for protected bandwidth 2.0dB
Geographical advantage 4.0dB

EIRP needed 47.4dBw

A 1.2-meter dish at remote

RX gain at 12.5GHz 42.0dBi
TX gain at 14.25GHz 43.2dBi

Output backoff HPA 3dB
Geographical advantage

Differences
12.5GHz 5.4dB Power 3.46 W
14.25GHz 4.2dB Power 2.63 W
As the 1.2-meter will not work with a 2 W transmitter, the next analysis is using a 1.8-meter dish.

A 1.8-meter dish as remote

RX gain at 12.5GHz 45.5dBi
TX gain at 14.25GHz 46.7dBi

Output backoff HPA 3dB
Geographical advantage 3dB

Differences
12.5GHz 1.9dB Power 1.5 W
14.25GHz 0.7dB Power 1.17 W
Checking the reverse:

A 1.8-meter dish in Cork

Maximum EIRP required at 0dBK contour: 54.8dBw
Adjustment for protected bandwidth: 2.0dB
Geographical advantage: 4.0dB

EIRP needed: 48.8dBw

A 2.4-meter dish at remote

RX gain at 12.5GHz: 48.0dBi
TX gain at 14.25GHz: 49.2dBi

Output backoff HPA: 3dB
Geographical advantage: 3dB

Differences
12.5GHz 0.8dB Power 1.2 W
14.25GHz n/a Power n/a W

For a circuit of 128Kb/s a 2.4-meter dish at the centre and a 1.8-meter dish at the remote is required.
3. Emergency Control vehicle

3.1. Existing Solutions

As part of the local area emergency response the Southern Health Board has, at present, a converted large solid base lorry to act as a control and communication vehicle. This vehicle also doubles as a transporter for both people and equipment. The communication capability of this vehicle was limited to the technology available at the time of design and the fact that it was built as a general vehicle rather than a specific design for any one of its uses. The phone communications are provided via a cable, which can be connected, to the nearest telecom provider Distribution Point (DP), or via the Boards own VHF radio system. In the event of a large-scale disaster the local communication infrastructure may be out of order and except for the VHF channels the vehicle could be isolated.

Consequently the size of the present vehicle was a cause for concern as the space needed for turning or parking it is extremely large. The terrain covered by the Board contains narrow streets in the older part of Cork City and the narrow twisty roads in the rural areas.

In looking at existing emergency control vehicles the most suitable communications were found in the one used by the American Federal Emergency Management Agency (FEMA). This is a 30-foot long communications van mounted on a Kenworth chassis with a total weight of 20 tonnes. The rear section of the roof opens to reveal a 2.4-meter satellite antenna, while the rest of the roof contains antennas for use with its radio suite. The inside of the van houses the
screen room that contains its communications equipment and a small office/work area in the front section (http://www.fema.gov/r-n-r/mers01.htm - introduction).

Figure 3-1  FEMA Emergency Management Vehicle

Due to the fact that a 2.4-meter satellite antenna is on board, the width of the vehicle must allow for the encasing of the dish plus room for it to be hydraulically moved into position. The MRV as it is called provides an interface to a variety of communications media. It contains High Frequency (HF) Radios; Very High Frequency (VHF) Radios and Ultra High Frequency (UHF) Radios, all with telephone interface capability. It also contains a Ku band satellite system that can provide connectivity for telephones, Local and Wide Area Network (LAN/WAN), compressed video teleconferencing, and Broadcast Video. There are also computers with scanning, printing, copying and facsimile capabilities. The MRV also has a small telephone switch to provide limited telephone support. All equipment is stored in two rows of Racks down either side of the chassis allowing a walkway between for maintenance.

Companies like Daimler Chrysler Aerospace AG (http://www.dasa.com/) manufacture large military specified communications vehicles for both terrestrial point to multi-point and satellite.
Another vehicle with large Satcom equipment systems is made by Nera (http://www.nera.no/) in Norway. Their integrated products are more designed for...
Outside broadcast (TV) rather than low data transmissions of less than 2Mbs. They design custom built vans with roof opening like the FEMA truck from which the dish is raised and pointed automatically.

The health services see communications as an add on and the communications vehicles that have been designed have been done so in a haphazard or once off way. For example is the Health / Rescue Services of - New South Wales emergency services (http://www.fast.net.au/suthoses) have modified vehicles to suit their requirements. A command vehicle for bush search and rescue is a single body vehicle with office and power generation functionality. The size of this vehicle is more in keeping with the Board’s requirements but to locate a dish in or on such a vehicle would cause a major problem

Figure 3-4 A Single Body Forward Command Vehicle

They also have a Troop Carrier which is used to carry 11 staff and also pull a trailer of up to 2 tonnes. The trailer in this case is just for equipment.
3.2. Applicability of currently available Hardware

Having examined the different systems available it was decided that the connectivity of the FEMA truck was the ultimate but the agility of the Australian troop carrier / trailer was also required. With this as the starting point, a vehicle that would be suitable to Irish terrain and give the best of both systems would be incorporated in the design of the FECV.

Guidelines for the requirements of a communications / control vehicle can be found at [http://hoshi.cic.sfu.ca/~epc/pub/manuals/en_mobile.html](http://hoshi.cic.sfu.ca/~epc/pub/manuals/en_mobile.html) as part of the Emergency Preparedness Canada site. This document is good on the general equipment needed and the pointers for chassis design were followed and looked on as a starting point thus not needing to re inventing the wheel. These guidelines were modified so to reflect the Southern Health Board’s requirements.

3.3. Relevant Literature Search

There are a large number of Internet web sites with both information and guidelines in remote telemedicine, the main ones of which are listed below:

[http://194.70.69.3/ethos/tap/tap/3fa.htm](http://194.70.69.3/ethos/tap/tap/3fa.htm) which provides a list of European telemedical projects from which software and ideas have been used.


[http://www.fema.gov/r-n-r/frp/frpesl2.htm](http://www.fema.gov/r-n-r/frp/frpesl2.htm) FEMA communication plan
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(http://www.fema.gov/r-n-r/frp/frpesf10.htm) FEMA Hazard policy
4. Logistical Specifications

4.1. Application Specification

The applications to be used and tested are as follows.

The acquisition of ECG records by remote operators and the transmission of these to the vehicle and Cork University Hospital (CUH).

The use of digital camera to give on location pictures of injuries, to the CUH staff to aid in diagnostics.

Intranet access for all users on site to the Southern Health Board’s intranet server in Cork, this will allow access to information and databases as required. Internet access to the vehicle to allow access to databases as needed this could be over the link to the central site and then out to the Internet via a firewall or directly using Web-Sat services from Armstrong in Dublin where the earth station is situated (http://www.web-sat.com/). The DAMA service and the Web sat service are both on the W3 satellite at 7 degrees East, but not on the same polarization. This has caused problems in use of one dish at the remote site to access both services.

E-mail from the Southern Health Board internal Mail server to all staff on site, this will allow accurate transmission of information rather than giving medical details over the phone.

Video Conferencing from the vehicle to Cork, where the Southern Health Board has a video conference multiparty bridge, this will allow not alone staff in CUH but in other locations to get and give information in real time while keeping all other parties aware of the present position.

The transmission of film from the vehicle should also be tested, depending on the quality of this broadcast versus the bandwidth available.
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The final application is voice, the set up of calls within the site and to the central site at CUH via the GSM and Satellite networks giving quality not less than the present GSM clarity to all.

The above applications except for video conferencing are at present being run by the Southern Health Board over 64Kb circuits from some locations back to Cork City. Thus we know from experience that so as long as the number of users or the bandwidth requirements of the applications is kept low the 64Kb limit will not be a problem. If video conferencing is used then 140Kb of bandwidth is required.

Figure 4-1 Schematic of equipment

4.2. Software Description

The Southern Health Board has an integrated Patient Information Management System (PIMS), which can be accessed via a bandwidth of 64kb or greater. The
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application is a client server one with a heavy client (a large amount of processing is done locally and only changes are saved to the server). This application has the health records of all patients within the Board's catchment area. This application can be published on a citrix server. (http://www.citrix.com/) Citrix is a service that allows client computers to attach to a citrix server, on this server client applications are run, the screens are the only information transmitted to the clients computer and key strokes are the only information sent to the server allowing a session to run over a circuit of 14Kbits.

As well as the application software the devices that the applications run on have to be tried and tested. The operators also have to be used to the look and feel of the application and be familiar with the hardware. Windows NT both Server and Workstation (http://www.microsoft.com/) running on a laptop that is reliable and robust. The droppable (up to 3 meters) and splash proof notebook from Panasonic (http://www.panasonic.com/computer/notebook/index.htm) has been tested, found to live up to its name and will be the basic platform used.

There is also information on the Web that can be beneficial to site operators either before or during an operation. So access to the Web, either via the Board's network, by dialup, or via a data channel on the satellite will be essential. The USA government emergency site at (http://www.fema.gov/) or sub site on hazard Materials (http://www.fema.gov/emi/hmep) are examples of sites that should be available.

4.3. Satellite System Design

The system needs to have coverage in the Cork Kerry area. Inmarsat, Orion, Astra and Eutelsat supply the commercial services with coverage in this area. The
Inmarsat systems (http://www.inmarsat.com/) have been designed for low bandwidth access from very small aperture terminals (VSAT), this system is dial on demand from the remote terminals. The fact that the satellite has to push a lot of power to the VSAT’s, means that the cost of usage per minute is high. The Orion system (http://www.orion.com/) conforms with the original Leased Line system of dedicated bandwidth from point A to B and web access via Internet Service Providers (ISP). The Astra offering (http://www.astra.com/) is Web access, where the user accesses via a terrestrial link to the web but receives over the satellite down link. The systems supplied by Eutelsat (http://www.eutelsat.com/) are leased line, dial on demand using Demand Assigned Multiple Access (DAMA) and Web access using a low bandwidth up link and higher speed down link this is supplied via Websat (http://www.websat.com/).

Figure 4-2 Different coverage characteristics
Having examined the various services available a DAMA service is the most cost effective for an emergency service, as one hopes it will never be used. This option keeps costs to a minimum as calls or services are charged per usage. If a terminal is set up and registered with the service provider then the station can then be switched off. When it is switched on again it will register itself with the satellite management centre and be able to make the desired connections. The only difference between the dishes is that one of the dishes has to have the ability to move. If it moves a small distance then system changes for echo cancellation are not necessary but for larger moves the management centre needs to be informed of the coordinates of the site where the station will be switched on. These coordinates can be got from an Ambulance Global Positioning System (GPS) in CUH, a hand held GPS, or from packages as accessible as Microsoft Encarta World Atlas.

4.4. **Sizing of communications equipment racks**

Communications Racks are used in the FEMA truck to house the communications equipment. By having the equipment rack mountable it provides stability (during movement) and security (behind locked doors) away from probing fingers. The normal size of these racks is 600mm by 800mm and 42U (2 meters high). Having all equipment rack mountable, and for mobile equipment to be stored in cabinets that can be locked, is the preferred procedure. The cabinets should have padded insides to protect equipment from damage.
4.5. Sizing of equipments housing

The present vehicle is a large single body truck which is slow and takes up a lot of space but on the other hand has work space as well as tea making and a rest location. It was decided to use a trailer, as it cost for the space provided is very good. It can be towed at speed to a location and then left while the vehicle that towed it can be used for other work.

The commercial and available sizings of trailers determine the ones that can be used. The following is a typical specification by a manufacture of trailers for the Irish market:

<table>
<thead>
<tr>
<th>Specification</th>
<th>Measurement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal Length (from rear door to taper)</td>
<td>3.66m (144&quot;)</td>
</tr>
<tr>
<td>Internal Length (from rear door to point)</td>
<td>4.19m (164&quot;)</td>
</tr>
<tr>
<td>Internal Width</td>
<td>1.73m (68&quot;)</td>
</tr>
<tr>
<td>Headroom</td>
<td>2.13m (84&quot;)</td>
</tr>
<tr>
<td>Max. Gross Weight</td>
<td>3500kg</td>
</tr>
<tr>
<td>Unladen Weight</td>
<td>1085kg</td>
</tr>
</tbody>
</table>

Table 4-1 Commercial Sizing of trailers for Irish Market

Taking these internal measurements, a 1.2 meter Dish will fit in the 1.73 meter width given and two 600mm by 800mm racks will fit (one at either side) and should be placed as close to the axle as possible to give a smoother ride. The area behind these should store the satellite dish and the generator as well as some fuel. The main fuel supply should be arranged separately. The front part would house worktop and administrative area.

4.6. Definition of Ergonomic Situation

In the development and design of the interior, the following should be followed:
4.6.1. Cabinets, Desks, and Work Surfaces

Pull-out or lift-up work surfaces can provide flexibility when working surfaces are required, yet can be stored when additional seating or standing room is necessary. Acetate sheets, or hinged plexiglass on walls and tabletops, under which maps or charts can be placed, permit marking of tactical information while keeping the documents clean for future operations.

Counters should be designed and constructed as per the following specifications:
- Of lighter colours, to reflect available light
- Of a non-reflective surface to reduce glare
- Of stain, mark, and chip resistant material
- With rounded, rather than right-angled corners
- Of a clean surface that can be wiped clean.

Desks and similar working surfaces should be:
- At a proper working height, relative to supplied chairs
- Designed with a knee-well, which should accept the intended chair, both to reduce operator fatigue, as well as for space efficiency.

Consideration should be given to mounting radios, telephones, etc., on the wall or vertical surface immediately above the relevant communicator's position, to maximize the working counter surface. The controls should be within comfortable reach of the seated operator. Pre-positioned telephone, power outlets (220 volt) and light at each work position will increase flexibility and reduce the number of cords and wires.

The inside of drawers used to contain fragile equipment should be lined with foam rubber or similar energy-absorbing material. All moveable objects should be
secured in transit by using velcro bases, lips on shelves, tethers to walls, etc. thus ensuring that vulnerable items can be protected.

4.6.2. **Flooring**

Flooring should be selected that is:

- Of a dark colour, to avoid showing dirt, marks, or scuffs
- Of a non-slip design, especially when wet
- A durable, heavy-duty industrial type, rather than carpet, to withstand wear and avoid stains
- Without small, deep, close grooves that retain dirt and hinder cleaning.

4.6.3. **Walls**

Sound-deadening carpet, particularly of the type used in recording studios, should be considered for the walls of high noise areas.

White boards can provide for the temporary display of information or maps, etc., during an operation.

4.6.4. **Lighting**

Lighting intended for counters, working surfaces, and display boards should be directed at the surface and shaded from operators. Lighting (particularly neon tubes) should be protected from breakage. Incandescent lights should have impact-resistant lenses that will not melt or distort from the heat of extended usage.
Lighting should be designed and directed so as not to:

Reflect in communicator's eyes

Reflect on computer terminal screens.

A directional or portable light should be available to allow work to be carried out on equipment.

4.6.5. Ceiling

All ceiling mounted equipment (air conditioning units, etc.), should have padded perimeters to avoid head injuries.

Insulation is needed on the ceiling. This will also protect the equipment from weeping (due to variation in temp between inside and out). However if roof is translucent then less light will be needed within the vehicle. So a trade off between them is required.

4.6.6. Seating

Where seats will be occupied for a long period (e.g. dispatchers, communicators, etc.), seats permanently mounted to the floor should be:

Equipped with padded armrests and adjustable lumbar support

Capable of forward/backward movement

Ability to rotate.

4.6.7. Heating/Air Conditioning

Air conditioning, heating, and generator units for the interior of the vehicle should be selected with quietness in operation as a key requirement. Communication racks have built in air circulation fans used with adjustable grills to be vented outdoors via windows and doors.
4.7. Identification of equipment to be used

4.7.1. Telephone

Telephone connectivity will be centred on a Private Automatic Branch Exchange (PABX). This will need interfaces with landlines, GSM, satellite and the LAN. The Nortel option 11 mini (www.nortelnetworks.com) is a suitable PABX as it has hard wired phones for use by the operators within the vehicle. Other extensions will be connected to DECT\(^1\) portable phones and/or IP mobile communication (IP telecommunicator). The use of these as opposed to GSM mobiles for calls between staff locally will ensure that the GSM cell channels will not be used up, for on site calls. Trunk positions on the PABX will connect to the GSM network, if this network is available. This can be done via a GSM to land line interface box. The phone should have its PIN removed so that at power up the line is accessible to the PABX. The GSM service provider can give priority calling, this allows calls to be made when the GSM network is congested but up. Other trunk positions will be PSTN and wired from a Main Distribution Frame (MDF) via a long cable to a Telco distribution point nearest the site. This cable would need to be approximately 50m in length. Caution should be taken when running this cable so as not to impede other workers on site. The third trunk access will be via the satellite link and depending on the satellite presentation, they will connect to analogue trunk

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\(^1\) DECT is a European standard for digital cordless communication, operating in a harmonised frequency band throughout Europe, 1880-1900 MHz. DECT is intended to provide high quality, short range cordless communication, and can be used in a variety of voice and data applications, such as single line residential systems, office PABX systems, public access systems and data LANs. The DECT Common Interface is ETS 300 175. This standard describes the basic features and technical parameters of DECT. All DECT equipment operates with a maximum transmission power of 250 mW, with a radio range outdoor typically up to 200 metres.
positions (RJ11) or IP card e.g. (Nortel ITG card) where the interface is Ethernet RJ45.

4.7.2. Antennae

Antennae should be positioned on the roof of the vehicle at the rear over the satellite storage area, so that in the event of water leaking the communications area will not be affected.

GSM antenna should be centered on the roof as much as possible to avoid interference with the signals in the trailer. All cables should be well marked so that in the case of a fault they can be easily traced and removed.

4.7.3. Local Area Network (LAN)

The applications such as the Patients Information Management System (PIMS) are accessed via computers; these computers are networked locally forming the LAN, which in turn is connected back to the Southern Health Boards data network (SHB net). At the center of the vehicle’s LAN is a Smartswitch 2200 from Cabletron (http://www.cabletron.com/) which provides Data ports to link all network active equipment. One of these devices is the router, (Cisco 1700 series (http://www.cisco.com/)) this connects the LAN through the Satellite link back to the SHB net. The wiring should be to Cat 5 standard thus protecting the data from any interference caused by the radio equipment.
4.7.4. Radio Equipment

There are two types of radio equipment. One standard VHF /UHF transmission system to contact the Southern Health Boards Ambulance Network. The other, using the Roamabout product from Cabletron, uses a point to multi point Spread Spectrum technology at 2.4Ghz to connect computers to a LAN. The base station is directly connected to the LAN and an indoor omni directional antenna connects the remote sites via PCMCIA cards with a built in antenna installed in a laptop computer. This allows the user to move distances of about 50 meters from the vehicle and still have network coverage.
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The equipment is to the IEEE 802.11b standard, which works at a maximum bandwidth of 11Mbps and reduces to 2Mbps further from the antenna. By using the outdoor omni-directional antenna the gain is increased from 4 to 7dB. As can be seen from figure 4-4 if in free space the dB receive level decreases as one moves from the antenna by having the power at maximum permitted is recommended.

Coverage using an Omni Directional Antenna

![Coverage Diagram](image)

**Figure 4-4** Omni-Directional Coverage

### 4.7.5. Computers

The use of computers within the vehicle should be confined to rack mountable ones as safe transportation is an issue. However rack mountable computers are very expensive, but as motherboards in standard computers are decreasing in size it is possible to secure a standard desk top computer to a rack shelf with screws. Using such a configuration for a local login server and file server. This allows for safe transportation and saves money. Laptops are ideal for field operators using the Roamabout PCMCIA cards as mentioned earlier some of these can be easy to carry.
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and rugged (http://www.panasonic.com/computer/notebook/index.htm). With Laptop screens taking less space and docking stations easy to store it is more convenient to have laptops within the vehicle also. The other advantage is the laptop doesn’t need power at power-up nor does an interruption interfere with their operation. As these are used for emergencies a spare charged battery will be carried.

Computer screens if used should be positioned to avoid reflection or glare from windows. Adjacent windows should have shades or blinds to prevent backlighting. All computers are capable of stand-alone working if the LAN fails.

4.7.6. Television

TV-VCR capability is required, this can be used to record/playback news or footage taped locally. UHF/VHF Cats ears can be used for local TV reception. A combined TV-VCR unit is the most space efficient, however if either module fails, the entire unit will have to be replaced. Where units are separate, replacement of either piece is facilitated due to common availability. A TV monitor on a rotating stand can permit maximum visibility where various seating configurations are in use. As this unit is not critical the choice is in favour of space saving.

4.7.7. Satellite interfaces

Included in the rack is the RF / Modem, which powers the Satellite dish transmitter. Companies such as Scientific Atlanta, Comsat Laboratories and Indra (http://www.scialt.com/ , http://www.comsat.com/ or http://www.indra.com/) manufacture such satellite modems. These devices provide interfaces such as X21 Data and or RJ11 for voice, as well as Ethernet RJ45 and or RJ11 for voice. The power requirements for the Scientific Atlanta 8000 RF with one Chassis and a
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2.5W outdoor unit is 165W if this is upped to a four chassis the power required is 300W.

4.7.8. Uninterruptible Power Supply

UPS are designed to prevent spikes, blackouts, sags, surges, etc. from reaching the system. They filter out supply line fluctuations and isolate the equipment from large disturbances by internally disconnecting from the mains and supplying power from their internal batteries until normal mains supply returns. In the vehicle an APC (http://www.apc.com/) rack mountable UPS provides power for essential equipment until standby generator is activated, the UPS will also smooth the generator output protecting the equipment against spikes and browning.

To size an UPS assumptions have to be made about the equipment needing power.

An equipment list was drawn up and with an UPS sizing package assuming all these units were on an UPS was picked these calculations can be seen in table 4-2.

The APC SU3000MINET will supply power for 44 minutes. This will give time for both the generator and satellite to be put working.

### UPS Selector

| Recommended Solutions | | |
|-----------------------|------------------|------------------|------------------|

The following APC solutions have been found to be most compatible with your requirements.

<table>
<thead>
<tr>
<th>Model #</th>
<th>Smart-UPS 3000 RM 5U + (1) Battery Packs</th>
<th>Smart-UPS 2200 RM 5U XL + (1) Battery Packs</th>
<th>Smart-UPS 2200 RM 5U XL + (2) Battery Packs</th>
</tr>
</thead>
<tbody>
<tr>
<td>SU3000RMINET + (1)</td>
<td>SU2200RMXLINET + (1) SU48RMXLBP</td>
<td>SU2200RMXLINET + (2) SU48RMXLBP</td>
<td></td>
</tr>
<tr>
<td>SU48BP</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SU3000RMINET Data Sheet</td>
<td>SU2200RMXLINET Data Sheet</td>
<td>SU2200RMXLINET Data Sheet</td>
<td></td>
</tr>
<tr>
<td>44 minutes</td>
<td>78 minutes</td>
<td>149 minutes</td>
<td></td>
</tr>
<tr>
<td>50 %</td>
<td>81 %</td>
<td>81 %</td>
<td></td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Capacity Used</th>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Product Line Information</td>
<td>Smart-UPS RM</td>
<td>Smart-UPS RM</td>
<td>Smart-UPS RM</td>
</tr>
<tr>
<td>Voltage Output</td>
<td>230</td>
<td>230</td>
<td>230</td>
</tr>
<tr>
<td>Voltage Input</td>
<td>230</td>
<td>230</td>
<td>230</td>
</tr>
<tr>
<td>Connections</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Input Plug:**
IEC-320 C19 inlet
Output Receptacles:
(8) IEC-320-C13, (1) IEC-320-C19

**Input Plug:**
IEC-320 C20 rewirable connector for user cord conn
Output Receptacles:
(8) IEC-320-C13, (1) IEC-320-C19

**Input Plug:**
IEC-320 C20 rewirable connector for user cord conn
Output Receptacles:
(8) IEC-320-C13, (1) IEC-320-C19

<table>
<thead>
<tr>
<th>Included Software</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• PowerChute Smart-UPS Bundle</td>
<td>• PowerChute Smart-UPS Bundle</td>
<td>• PowerChute Smart-UPS Bundle</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UPS Options</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Management Devices</td>
<td>• Management Devices</td>
<td>• Management Devices</td>
<td></td>
</tr>
<tr>
<td>• Mounting Kits</td>
<td>• Mounting Kits</td>
<td>• Mounting Kits</td>
<td></td>
</tr>
<tr>
<td>• Replacement Battery Cartridges</td>
<td>• Replacement Battery Cartridges</td>
<td>• Replacement Battery Cartridges</td>
<td></td>
</tr>
<tr>
<td>• Service</td>
<td>• Service</td>
<td>• Service</td>
<td></td>
</tr>
<tr>
<td>• Software</td>
<td>• Software</td>
<td>• Software</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Features</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>

**Your Device List:**

<table>
<thead>
<tr>
<th>Device</th>
<th>Total Power (Watts)</th>
<th>Operating Voltages</th>
<th>Quantity</th>
<th>Total Power (VA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cabletron Systems Airport</td>
<td>179</td>
<td>230</td>
<td>1</td>
<td>256</td>
</tr>
<tr>
<td>Cabletron Systems SmartSwitch 2200</td>
<td>107</td>
<td>230</td>
<td>1</td>
<td>153</td>
</tr>
<tr>
<td>Cisco 1720 access router</td>
<td>20</td>
<td>230</td>
<td>1</td>
<td>29</td>
</tr>
</tbody>
</table>
4.7.9. Generator

The generator is stored in the rear of the trailer. From the calculations above for sizing the UPS, the generator would have to be greater than 2KW a size of at least 5KW being advisable as UPS is sized only for devices that need to be working on arrival at a site. Others power requirements would include:
Charging of devices:

<table>
<thead>
<tr>
<th>Device</th>
<th>Power Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laptops</td>
<td>300W</td>
</tr>
<tr>
<td>Portable phones</td>
<td>200W</td>
</tr>
<tr>
<td>Mobiles</td>
<td>100W</td>
</tr>
<tr>
<td>Lamps</td>
<td>200W</td>
</tr>
<tr>
<td>Radios</td>
<td>200W</td>
</tr>
<tr>
<td>Tea making facilities</td>
<td>2000W</td>
</tr>
<tr>
<td>Giving a total of</td>
<td>3,000W</td>
</tr>
</tbody>
</table>

**Table 4-3 Calculation of power requirements**

The generator, when running, should be placed in a ventilated area where the fumes will not enter the trailer. As the generator is rainproof its location can be outside and down wind to keep the noise and fumes to a minimum. The number of cables should also be kept to a minimum and if possible fenced off from the public. The fuel used by the generator is diesel and even though this is not as highly flammable as petrol the storage of diesel is more messy than dangerous. As all Ambulance vehicles use diesel if the generator was running low then some could be acquired.
5. Forward Emergency Control Vehicle Design

5.1. System Choices

Having decided on DAMA technology the choice is between Inmarsat and Eutelsat. Effectively the choice here was between low call charges and a large dish from Eutelsat or a smaller dish and higher calls charges for Inmarsat. As low prices are a priority on low on going charges the decision was to go with the new DAMA services from Eutelsat. As the costs of these systems are commercially sensitive I cannot give them here.

The choices now are three fold:

Arcanet services from INDRA in Spain, which provides bandwidth in 8K segments up to approximately 32Kb. The Southern Health Board in late 1998 using a briefcase and 1.2m system tested this service. Its accessibility and voice quality was good, but its data ability was only suitable for asynchronous type applications.
The Skylinx service from Scientific Atlanta now (Viasat (http://www.viasat.com/)) provides for bandwidth up to 160Kbps with voice interface (RJ11) and a data interface (RS 232).

The Linkway service from Comsat laboratories (http://www.comsat.com/) that provides bandwidth from 64Kbps to 2Mbps the interfaces provided are PRI and Ethernet with BRI interfaces coming soon.

### 5.2. Link specification

To cater for the required applications a link bandwidth of 140Kbps was chosen.

This allows the largest bandwidth user videoconference at 128Kbps and 8Kbps voice call to work simultaneously. The other factor that needs to be taken into account is the geographic location of the sites.

![Detailed Map of Southern Health Board Region](image)
A fresh look at the provision of bandwidth to a health agency

The Southern health board’s coverage area can be marked out by the following set of lines W 7.40' to W 10.20' and N 51.30' to N 52.35'. Working back to a dish located in Cork University Hospital at N 51.88' W 8.51'. The dish size and power output is the remaining factoring needed to produce a link budget. Initially a dish size of 1.2 meters on the vehicle was suggested as this is the largest fully set-up that could fit in the vehicle and is also easy to move about and set-up.

![Figure 5-3 Footprint of Eutelsat W3](image_url)
<table>
<thead>
<tr>
<th>Bandwidth</th>
<th>140KBps</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overheads</td>
<td>no overhead</td>
</tr>
<tr>
<td>FEC</td>
<td>1/2</td>
</tr>
<tr>
<td>Modulation</td>
<td>QPSK</td>
</tr>
<tr>
<td>Baud Rate</td>
<td>140 kbauds</td>
</tr>
<tr>
<td>Eb/No</td>
<td>6.1 dB</td>
</tr>
<tr>
<td>R.M</td>
<td>1.3 dB</td>
</tr>
<tr>
<td>C/No</td>
<td>58.9 dBHz</td>
</tr>
</tbody>
</table>

Receive 1.2 m

| G/T | 19.5 dBK |
| Xpol | 35 dB |
| SSR | 0.67% |

Maximum EIRP required at 0 dBK contour: 56.4 dBW

Receive 1.8 m

| G/T | 23.0 dBK |
| Xpol | 35 dB |
| SSR | 0.39% |

Maximum EIRP required at 0 dBK contour: 54.7 dBW

Receive 2.4 m

| G/T | 25.5 dBK |
| Xpol | 35 dB |
| SSR | 0.32% |

Maximum EIRP required at 0 dBK contour: 53.2 dBW

Uplink Satellite G/T on W3 txp F1 at 7° East

Cork: 4.95 dBK
Worst case for the remote: 4.0 dBK

So for example if you want transmit via Remote 1.2 m and receive with the 1.8m the maximum EIRP required will be:

54.7 - 4.0 = 50.7 dBW.

The size of HPA Needed from remote dish of 1.2 meters

EIRP max at 0 dBK: 54.7 dBW
EIRP requested at 0 dBK: 52.7 dBw (in protected bandwidth)
A fresh look at the provision of bandwidth to a health agency

Geographical advantage: + 4.0 dBK (worst case in Ireland on W3 F1)
EIRP needed at + 4.0 dBK = 52.7 - 4.0

<table>
<thead>
<tr>
<th>Tx Gain at 14.25 GHz (1.2m): 43.2 dBi (assumed by EUTELSAT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output backoff HPA</td>
</tr>
</tbody>
</table>

HPA needed

2.4m dish used in reception

EIRP max at 0 dBK : 53.2 dBW
EIRP requested at 0 dBK : 51.2 dBw (in protected bandwidth)
Geographical advantage: + 4.0 dBK (worst case in Ireland on W3 F1)
EIRP needed at + 4.0 dBK 51.2 - 4.0

<table>
<thead>
<tr>
<th>Tx Gain at 14.25 GHz (1.2m): 43.2 dBi (assumed by EUTELSAT)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Output backoff HPA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>HPA needed</th>
</tr>
</thead>
<tbody>
<tr>
<td>7.2 W</td>
</tr>
</tbody>
</table>

Table 5-1  Power requirements with 1.2 and 1.8 meter dishes

As the maximum power available on a 1.2 meter dish is 2.5W. The next set of calculations that were done was for a 1.8 meter dish at the remote having a power of 2.5W and with 1.8 or 2.4 meter in CUH.

A 1.8 m dish in reception.

EIRP max at 0 dBK : 54.7 dBW
EIRP requested at 0 dBK : 52.7 dBw (in protected bandwidth)
Geographical advantage: + 4.0 dBK (worst case in Ireland on W3 F1)
EIRP needed at + 4.0 dBK 52.7 - 4.0

Tx Gain at 14.25 GHz (1.8m): 46.7 dBi (assumed by EUTELSAT)
Tx Gain at 14.25 GHz (2.4m): 49.2 dBi (assumed by EUTELSAT)

Output backoff HPA

3 dB (assumed by EUTELSAT)
A fresh look at the provision of bandwidth to a health agency

HPA needed with 1.8m in Tx at +4.0 dBK contour 3.2 W
HPA needed with 1.8m in Tx at +5.0 dBK contour 2.5 W

HPA needed with 2.4m in Tx at +4.0 dBK contour 1.8 W
HPA needed with 2.4m in Tx at +5.0 dBK contour 1.4 W

A 2.4 m dish in reception.

EIRP max at 0 dBK: 53.2 dBW
EIRP requested at 0 dBK: 51.2 dBw (in protected bandwidth)
Geographical advantage: +4.0 dBK (worst case in Ireland on W3 F1)
+5.0 dBK in center
EIRP needed at +5.0 dBK 51.2 - 5.0 47.2 dBW
EIRP needed at +4.0 dBK 51.2 - 4.1 46.2 dBW

Tx Gain at 14.25 GHz (1.8m): 46.7 dBi (assumed by EUTELSAT)
Tx Gain at 14.25 GHz (2.4m): 49.2 dBi (assumed by EUTELSAT)

Output backoff HPA 3 dB (assumed by EUTELSAT)

HPA needed with 1.8m in Tx at +4.0 dBK contour 2.3 W
HPA needed with 1.8m in Tx at +5.0 dBK contour 1.8 W

HPA needed with 2.4m in Tx at +4.0 dBK contour 1.3 W
HPA needed with 2.4m in Tx at +5.0 dBK contour 1.0 W

Table 5-2 Power requirements with 1.8 and 2.4 meter dishes

Summarizing the above if a 1.8 m dish is in CUH then on the vehicle the following is needed a 1.2m dish with 8W output which is very high power for the size of dish and the cost is $ 5,000 for the extra power 2.5W to 8W where the extra size increase 1.2m to 1.8 is only $300.

A 1.8m dish with 8W output is needed to work in the entire region.

With a 2.4 m dish is in CUH then on the vehicle the following is needed a

A 1.2m dish with 8W output or a 1.8m dish with 2.5W output will work in the entire region
5.3. System Kitlist Requested

Thus the configuration required is a 2.4m Dish in Cork University Hospital with 2.5W power output and a 1.8m dish in the vehicle with 2.5W power output and not a 1.2m dish as was initially hoped for.

2. Skylinx 8000 Single Channel Remote Terminal (1.8-Meter, 2.5-Watt ORU, Voice/Data)
   a. Model 1194-990 1.8-Meter Ku-Band Antenna with ETSI Type Approval
   b. Reject Filter
   c. ORU Mounting Bracket
   d. Model 8615 2.5-Watt Ku-Band ORU with Integration Materials
   e. OMT Kit
   f. LNB
   g. 100-ft IFL Cable
   h. Integration Material
   i. Series 8000 RF Chassis for up to 3 channel units
   j. Series 8000 RF Indoor Module
   k. Series 8000 CU (Voice, Fax and Data) with Analog and Digital Interface, Fax/Data Relay
   l. G.729 8kbps Voice
   m. Chassis Interconnect Cables

3. Skylinx 8000 Three Channel Remote Terminal (1.8-Meter, 2.5-Watt ORU, Voice/Data, Remote Connect)
   a. Model 1244-930 2.4-Meter Ku-Band Antenna with ETSI Type Approval
   b. Reject Filter
   c. ORU Mounting Bracket
   d. Model 8615 2.5-Watt Ku-Band ORU with Integration Materials
   e. OMT Kit
   f. LNB
   g. 100-ft IFL Cable
   h. Integration Material
   i. Series 8000 RF Chassis for up to 3 channel units
   j. Series 8000 RF Indoor Module
   k. Series 8000 IF Chassis for up to 4 channel units
   l. Series 8000 CU (Voice, Fax and Data) with Analog and Digital Interface, Fax/Data Relay
   m. G.729 8kbps Voice
   n. Series 8000 Remote Connect Channel Unit
   o. Chassis Interconnect Cables

Table 5-3 Kit list of Satcom equipment needed
Table 5-3 shows the kit list of equipment needed to connect to the Skylinx service on Eutelsat W3.

5.4. The vehicle construction

The Chassis chosen has features that make it suitable for the emergency vehicle. The body is made up of an area 3.66 meters by 1.73 meters and a taper area that forms a triangle over the tow bar for 0.53 meters. This allows for tighter turning and easier parking of the vehicle. The gap between the axles allows for a smoother drive on rough roads and greater stability at higher speeds on the open road. The floor is covered in a non-slip material that can be washed easily. The rear door allows for easy loading and unloading of equipment while the front door lets operatives access the vehicle operational area without interfering with the communications equipment. The dish whether 1.2m or 1.8m will fit in but the 1.8m will need to have the Outdoor unit remove deach time and this will slow down deployment.
The racks act as a natural break between the administration area and the dish and generator storage area. They are the heaviest items in the vehicle and by having one at either side and over the axle area give for a smoother and more balanced drive.
6. Building FECV 1 its components and testing

6.1. Testing and integration

In this section the individual unit testing, the integration of the equipment and the commissioning of the FECV1 the trailer version is examined.

At the time of building FECV1 as the Skylinks equipment was not delivered and so as not to delay the project, the Satellite equipment used was the Web-sat offering as it is on the same satellite and all procedures put in place would transfer to the Skylinks when it arrived in Ireland.

6.1.1. The Phone system

The Phone System chosen was, Nortel’s Option 11c mini with Trunk Card Digital Extensions and IP telecommunicator card. (http://www.nortel.com/)
Its IP card was configured using MAT software from Nortel. Standard telephone lines (PSTN) were connected to the Trunk positions, this allowed Digital Extensions to make and receive calls, which proved the PABX was operational. The SHB standard is to dial zero for an outside line and then dial on and this was implemented on the PABX.

Next the client software was loaded on a laptop, which was connected to the switch via a crossover cable to provide Ethernet Connectivity. The ports of the PABX were then pinged to prove that the PC and IP card in the PABX were connected. The client software was run and the PC client registered. Calls to and from Digital Extensions were made. A problem was found with the laptop in that sometimes it was not possible to make calls. By making sure the sound card in the laptop was set to Duplex working and that there were no IRQ conflicts, the problem was solved.
6.1.2. GSM Gateway

To allow the PABX to make calls over the GSM network a gateway is required. The one chosen is the premicell supplied by Nokia (http://www.nokia.com/). It has the features of a normal mobile except has no keypad a standard phone connected to the RJ11 interfaces provides handset features. It was tested with an analogue phone and calls were made to and from it proving that it worked as expected.

6.1.3. Data Hub

The hub chosen was a Cabletron Data Switch, this was powered up and given an IP address via its management terminal. Two computers were attached to ports and they were set to ping each other and the switch itself, proving the ports and switch worked normally.

6.1.4. Wireless LAN

The Cabletron spread spectrum Roamabout device was powered up and given an IP address. Client software was installed on a laptop to access the device and an antenna PCMCIA card was installed. A distance of 10 - 15mtrs was obtained before contact with the base was lost. (Time out on Pings) by adding an antenna to the base device this distance increased to 30 - 50mtrs. This is dependant on obstacles in the transmission path as the frequency used is 2.4Ghz and buildings and solid objects attenuate the signal significantly more than air. (http://www.cabletron.com/)
6.1.5. Uninterruptible Power Supply

The APC UPS was connected to the 220 volts mains and fully charged. An Ethernet interface was connected and given an IP address. Thus allowing information to be received from the UPS e.g. percentage charge load temp etc. A load was connected to the UPS (a 2KW heater). The UPS was removed from the mains and discharged fully through the heater. The mains was then connected with the load still on and the UPS again supplied the load while being charged this as was expected. (http://www.apc.com/)

6.1.6. Generator

The generator was filled with diesel and started, when running smoothly a load was placed on the 220volt output and the power fed to the load. The was found to adequately supply the required power.
6.1.7. WEB SAT

The software application was loaded onto the computer, transmit and receive cards were also installed.

![Figure 6-3 Rear of computer housing Websat Tx and Rx cards](image)

The dish was set up to Eutelsat W3 at 7° East and the receive level measured on the computer. A level of 73% was achieved, for our footprint location this is a typical value. A text message was received from the earth station gateway in Dublin, which proved we were on the correct satellite then the transmit card connected to the dish. Our transmit signal was checked by the Web Sat staff and horizontal polarisation changes were made.

It was possible now to browse the web and send and receive mails.

6.1.8. Wiring

Wiring of the vehicle was done in as flexible way as possible. Having terminations in easy accessible locations will allow the crew to make connection as and when they are needed. All cables are to Cat5 standard and can be used for voice or data as required.
6.1.9. Electric Wiring

Before wiring the equipment on board it was important to have power to the equipment both while the vehicle is in storage / standby or at arrival at the site. While the vehicle is on standby it needs power to keep the UPS charged and to power a heater and or dehumifier. A requirement here is that when a callout happens the crew don’t have to open the vehicle to disconnect the power.

To solve this, connection points to external cables should be housed in a box outside the vehicle. There are two restraints involved, one the box can be easily opened and closed, the other is that it does not protrude beyond the widest part of the vehicle.
There are three such locations available, one on the front of the vehicle on the taper where it would be protected by the hitch, the other two are on either side of the vehicle over the mudguards where again it would be protected by the mudguards from being hit whilst driving. The operating crew when connecting the vehicle to the towing 4x4, must as part of the towing procedure connect the rear lights to the 4x4 by plugging in a plug from the vehicle and thus if the front position is chosen without having to move they can remove the power at the same time.

In Ireland the UK motor vehicles are right hand drive. Which has given rise to some of the roads being travelled by the vehicle being cambered towards the left side. The heaviest equipment should therefore be on the right hand, which is the side nearest centre of road. All cables and cable runs conform to the appropriate standards.

Figure 6-5 Enclosure with generator / mains changeover as well as PSTN and satellite leads
6.1.10. Types of supply

There is the potential of three forms of power supply:

- The UPS which can supply power to essential equipment on arrival at a site.
- A mains 220volt if available on site.
- A generator supply, which can supply all the power needs of the vehicle.

The UPS was dimensioned to supply equipment listed in table 4-2. The Satellite equipment and a light are also be powered via the UPS (to save power and for safety reasons. In relation to the Satellite equipment, the cables to the dish should not be powered while they are being worked on), thus these are switched independently.

If Mains power is available this can be connected in the same way as in the charging mode back at base. An extension lead with 13 Amp plug (which is the most common connection in Ireland) and 16 Amp socket is available within the vehicle. Within the connection enclosure a 16 Amp mounted plug point is mounted as the 220V interface.

Figure 6-6   Changeover, MCB's, Dado rail, and generator
6.1.11. The generator

The generator runs on diesel and has 5KW output the output power can be either 110V or 220V for this application the output will be fixed at 220V. The generator has attached a 16 Amp interface this lead can be connected to the 32 Amp plug in the enclosure as with the 16 Amp as the size of these connectors are different there cannot be any question of confusing a connection. The power from the generator first supplies power to extra lights, heaters and general sockets within the vehicle. If there is no Mains then by activating a change over switch the generator also powers the UPS and all devices, which it supports.

6.1.12. Telephony wiring

The hard-wired extensions and trunks from the PABX are made off on a patch panel from here the mobile interface is connected to the PABX. These are clearly marked should they need to be moved at a later date. All extensions are marked and the phones are also marked for ease of identification and installation. The mobile laptop has its extension clearly marked also. Extra analogue extensions are available and a cable is terminated on the patch panel and the other end has unterminated loose wires to either punch down on a strip or terminate at a screw connection. This work has to be done by a telecommunication technician, but having the cable available speeds up the task immensely. A number of computer points are also pre-wired, are marked as such, and made available in the cabinet.
6.1.13. The rack

As mentioned earlier the rack is on the side nearest the road centre and for balance should be positioned over the wheelbase. In installing the equipment in the rack the heaviest item (the UPS) is placed at the bottom, next is the battery which supplements the UPS itself. Next the Satellite equipment (Skylinx 8000 or the Websat Computer and screen). This is followed by the data switch the wireless LAN base station and the PABX as these are connected to the patch panel it is best keep them together.

Figure 6-7  Schematic of Rack
6.1.14. Desk

Forward from the rack a desk / worktop was installed, the outer rim is 208 cm long. Above this is a Dado rail, which provides mounting for power sockets and voice and data outlets. The power and the data are run separately and the ducts provide access between the rack and the outside and is used for the cables to the Dish, the multi-core phone cable, and power feeds to the switches on the side of the rack.

Figure 6-8 Fax on Desk

6.1.15. Antennae connections

The Satellite connections to the Dish use screw type couplers to allow the cable to be easily reconnected. The larger of the two is the higher powered transmit. If the cables were the same a simple colour code could be used.
6.1.16. Dish

The dish is stored in the area behind the rack and secured with ratchet straps.

![Figure 6-9 Ratchet connectors](image)

It is important not to hit the horn or to use the horn part of the assembly to move the dish as it can be moved out of alignment thus reducing the efficiency of the dish.

6.2. Integration testing

When all equipment was installed in the rack, the data / voice interconnections were put in place and a 220V mains fed to the rack supplying the vehicle and all equipment was powered on. Calls were successfully made from Digital Extensions to Digital Extensions. Calls were attempted to outside via Nokia premicell. This failed as the security number had not been entered. By disabling the security setting, this allowed the PABX to access out calls via the Nokia on power up.

A laptop with IP Telecommunicator software and spread spectrum software installed was connected to the phone system and it registered the laptop as a phone extension; this extension was then able to make internal and outside calls.
A fresh look at the provision of bandwidth to a health agency

The Web Sat computer was able to access the web, send and receive e-mails, but other machines were not. This was solved by installing NAT (network address translation) software on the web-sat computer. The installation was quite difficult, as we were not connecting directly to the Internet but via the web-sat domain and then onto the Internet. Having installed and configured the software all other computers on site were able to browse the Internet via the web-sat gateway. This could be used to access the Board’s network using a data Virtual Private Network (VPN) but the uplink speed is only suitable for browsing.

![Figure 6-10 IP setup](image)

6.3. The Controllers Desk and feedback

After an on-site meeting with the Ambulance controllers and the physically examined the vehicle and the location of desk generator dish etc. They made several request as follows.

- As two controllers work together, comfortable seating needs to be provided, ergonomically designed seating is necessary as the controller may need to be seated for hours on end. When picking the seating back support, and head rests need to be taken into account as well as the raising and lowering of the seat to suit the controller’s height etc.
A fresh look at the provision of bandwidth to a health agency

- VHF/UHF facilities to talk directly to ambulances on route and back to central control (if within range). An area on the left (as they sit) was identified for this and it has easy access to the outside for an external antennae. Two phones were provided to allow both controllers to be in contact with either operatives in the field or back to Cork University Hospital.

- Fax facility to send or receive written instructions or comments that are not in data file format or too complicated for verbal transmission. A laptop with e-mail and video applications, to establish picture contact with Cork University Hospital. This can also be used for group briefing from Cork University Hospital to the controllers.

- Another request was to be able to have GPS and maps on the laptop allow for accurate positioning of the site location.

Thus the following modifications / additions were made.

- Flexible seating was purchased
- VHF/ UHF desk top units were purchased
- The laptop had e-mail and realplayer software was installed.
- The requirement for a fax machine could be solved in two ways, an analogue card in the PABX or an Analogue Terminal Adaptor (ATA) in the base of a digital phone as only one analogue position was required the latter was used. This device is powered from a socket on the Dado rail.
6.4. Commissioning

With the vehicle fully fitted the next stage was to commission the system.

The vehicle was deployed in test conditions and the following stress testing was carried out. The loss of different components / connections and the resultant degradation of service was examined.

The vehicle was powered with 220V mains supply this was disconnected. The UPS alarmed and the laptops on the controller's desk went onto battery backup. The Cabletron switch alarmed that one of its 2 supplies was without power. The only failure was the fax machine on the Controllers desk as both the ATA and the Fax needed 220V and as this was not fed via the UPS, the heater / humidifier socket had no power also. The generator was started and put on-load. Now the heater...
socket was the only outlet not working. This was as planned as the potential load from this socket could drain the UPS in minutes.

By powering down the UPS with the 220V reconnected, only the laptops that were on the controller’s desk (which are hard wired RJ 45) were able to communicate with each other via the Cabletron data switch, but not with the outside world. As the rack power rail is fed from the UPS the power rail can be powered from the generator or 220V main by plugging into a socket on the desk that normally powers the UPS. This is not an expected event and a person would be required to unplug cables and use extension leads to power up the equipment.

As the test site had PSTN lines available these were connected to the PABX as well as the Nokia premicell. If any of the lines goes faulty and are disconnected then outgoing calls will fail on connecting to that line. If the circuit is the second and the access is linear then when there is one call on, the next call will fail. Only if somebody is trying to access the faulty line will the next line be reached and a successful call made. If the second circuit is faulty and the access is round robin then the ratio of failures to success, is the number of faulty lines to good ones.

In the normal set-up the Nokia premicell would be an access group and if PSTN lines were available then they would be added to the group. These would then be accessed by dialling zero followed by the public number. Access to satellite circuits with either RJ 11 or soft phone presentation would be by dialling the required Southern Health Board extension or VPN number.

The computers on site are connected either by RJ 45 cable to the Data Switch or via a spread spectrum PCMCIA card back to the Roamabout network interface which is in turn connected to the data switch via an RJ45 cable. When the Data
Switch was powered down then the laptops using the Spread spectrum could share files but not communicate with Cork University Hospital, the hard-wired computers could only work as stand-alone. When the power to the Roamabout was disconnected all computers worked on a stand-alone basis. With the power back on to all, except the website computer. All the laptops could share files but could not communicate with Cork University Hospital. Once this was powered up all communication was as before.

As the Satellite Dish is supported by a tripod style structure and as it remains assembled from the very first set up and alignment, much of the dish work is removed. On the initial construction of the dish housing the base was levelled and the rear leg of the base was pointed North South, this alignment was done with a simple compass and a plastic rod to remove metallic interference. On tracking a known T.V. channel on a satellite nearby, the elevation was roughly achieved then by moving further East, W3 7E was reached and a good signal was obtained. The dish was secured in place on initial transmission and then the dish was rotated to the correct polarisation. This setting is then recorded and marked on the dish mounting and associated with the site for the future.

On arrival at a location a level site is found and the dish to be positioned in a North South line is marked on the ground before the dish is moved into place. The dish is then moved into place with the rear leg parallel to the North South line, next the legs are levelled until all three are level and level with each other. Then the frame is secured in place. The next stage is the dish alignment. The dish alignment is a two stage operation first the large step, moving to a set location already marked for the site (or for a nearby one if the vehicle is being used on a new site). The second
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step is the fine adjustments to get the highest receive level possible. This is found by moving left / right and noting the level rise then fall and returning to the strongest level.
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7. Satellite systems new technologies & Building FECV 2

7.1. Satellite System

Having had FECV1 built and shown to all interested parties within the Board, the Irish emergencies services, the Irish Navy and even the RAF, extensive discussion followed.

From these extensive discussions with the groups, now that there was a working example of a vehicle, rather than when there were just being shown plans and concepts. The following main recommendations were made. It was recommended that the technology be shrunk into a ‘half rack’ and installed in a 4x4 or to be more specific an ISUZU trooper long wheel base.

At this stage the Scientific Atlanta equipment (now owned by ViaSat) arrived in Cork.

7.2. Satellite System

The equipment shipped was a 1.2m dish for the remote site and a 1.8 m dish for Cork University Hospital. This was the stock available for Eutelsat customers at the time the 1.8 m was assembled and installed on ambulance control in CUH.
Figure 7-1  CUH site

The 1.2 m was assembled and tested from grounds of CUH the dish was then transported to Nadd in north Cork which would be the 1.2 m test location for the next few months.

Figure 7-2  Shows lights on the modems during power up

On power up the fix light on the internal modem was red which informed us that the modems were not receiving the satellite carrier.

By panning the dish moving it left right until the Rx light went black and then green until it went position. The same procedure was carried out on the tilt up down this range is a lot smaller and again the centre position. A receive level of 15.9 Db at the Network Management Station NMS at Fucino in Italy was achieved.
Phone numbers were given to the 2 modems on the 1.2m dish
Channel 1 011024
Channel 2 011025

Phone numbers were given to the 3 modems on the 1.8m dish
Channel 1 Data
Channel 2 011022
Channel 3 011023

Calls from the 1.2 m to the 1.8 meter dish were made and the quality was very
good toll quality. Calls from the 1.2 m to Italy were good clarity but here was an
echo on voice transmitted to the NMS. This was explained, as the dish at the NMS
in Italy is 4.5 meters.

To allow PSTN users to access a site and check the quality an Italian PSTN
number was used 00 39 08 63 550 759 this was mapped to 001 024 channel 1 at the
A fresh look at the provision of bandwidth to a health agency

1.2 meter site. Test calls were made from GSM and PSTN lines and all users described the quality as better than expected and better than mobile to mobile. When calls made from the vehicle, using a GSM phones to Italy and back over the satellite to the dish, the time delay was noticeable and audible as the callers were able to hear both sides of the conversation.

Data connection was established and the initial bandwidth used was 32Kbps. Cisco routers were connected to both sides and when the Cisco at the 1.2m was connected the call was made and the routers connected. This allowed the ability to ping across the link for the first time. Rates of 621 ms with max of 631 ms were recorded for 1.2m to 1.8m while rates of 621 ms with max of 637 ms in the other direction. While connected to Southern Health Board’s network at 32Kbps, checks were made for Email response, then the bandwidth was upped to 48Kbps. Having succeeded at this it was upped to 64Kbps, but the calls repeatedly would fail. This call failure was put down to the power needed at the 1.2m dish to establish a call. By reverting to 56Kbps the call established easily. The ping delay now dropped to 601 ms, which would be the expected drop if a terrestrial circuit were changed from 32Kbps to 56Kbps.

The power was then reduced to stop any red flashes on the “Busy TX PWR” lamp. This lamp gives an indication of the transmit power, if this is nearing saturation then the lamp will change from Amber (the normal colour for an established call) to Red the error condition. Then the call was dropped and raised a few times to prove connection at 56Kbs.
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The next test to be carried out was the set-up of a data call to Ambulance control and then a voice call from a mobile via Fucino to the first channel. The following checks were carried out:

To test if any data bandwidth was lost during the voice call pinging across the data circuit was done, the ping speed remained the same, that gave an indication of no bandwidth loss.

If the power being transmitted is too large, the “Busy TX PWR” lamp changes from amber to red, it remained Amber and within limits.

To test if a fax transmission could take place over the voice channel. A fax call from PSTN lines via the Italian gateway was attempted, but resulted in “Line error”. Putting the circuit into store and forward status when fax calls were identified rectified this.

A number of file were transferred and the results and comparison to 32Kbps circuit are shown in table 7-1 below. These files are typical of those that would be sent in real life situations.

<table>
<thead>
<tr>
<th>file type</th>
<th>file size bytes</th>
<th>file size bits</th>
<th>time sec 32Kbps</th>
<th>tot sec 32Kbps</th>
<th>rate 32Kbps</th>
<th>time sec 56Kbps</th>
<th>tot sec 56Kbps</th>
<th>rate 56Kbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>visio</td>
<td>104,448</td>
<td>835,584</td>
<td>35</td>
<td>35</td>
<td>23.87</td>
<td>35</td>
<td>35</td>
<td>23.87</td>
</tr>
<tr>
<td>excel</td>
<td>24,064</td>
<td>192,512</td>
<td>8</td>
<td>8</td>
<td>24.06</td>
<td>8</td>
<td>8</td>
<td>24.06</td>
</tr>
<tr>
<td>small word</td>
<td>20,490</td>
<td>163,920</td>
<td>10</td>
<td>10</td>
<td>16.39</td>
<td>8</td>
<td>8</td>
<td>20.49</td>
</tr>
<tr>
<td>large word</td>
<td>3,141,632</td>
<td>25,133,056</td>
<td>45</td>
<td>945</td>
<td>26.60</td>
<td>9</td>
<td>50</td>
<td>42.60</td>
</tr>
<tr>
<td>powerpoint</td>
<td>186,880</td>
<td>1,495,040</td>
<td>60</td>
<td>60</td>
<td>24.92</td>
<td>28</td>
<td>28</td>
<td>53.39</td>
</tr>
</tbody>
</table>

Table 7-1 Size and speeds of file transfer over 32K and 56K links
7.3. **The use of two systems and one dish**

As discussed earlier a requirement is to browse the web to access certain sites. To transport 2 dishes and to set-up two would be both wasteful of space and an extra headache for the Ambulance staff on site. As the data circuit connects the site to the Southern Health Board’s network the internet could be used to access the web. The use of point-to-point bandwidth for browsing is an inefficient use of this band especially for down-loading data (the ratio of 1:10 is regarded as the norm for data to the web against data from the web). The integration of web-sat and the skylinx products, was investigated as both are on the one Satellite with web-sat being horizontal polarized and the skylinx having vertical polarisation. It is possible to get a microwave mixer to allow 2 transmit feeds and to receive 1 vertical, 1 horizontal polarised signal.

![OMT LNB and transmitters](image)

**Figure 7-5** OMT LNB and transmitters
In order to be compatible with our Prodelin dish (http://www.prodelin.com/) (1134-990) and feed (0800-1412) and our Orthogonal Mode Transducer OMT (0800-2598). A 4 port OMT was required to work with the Scientific Atlanta equipment. The Scientific Atlanta is vertically polarised and the web-sat application which is of horizontal polarity. Both of these are TX and Rx the second TX is 0.2watts and the total weight of its existing horn OMT LNB and transmitter is only 3.5 pounds. A 4 port Ku Band feed was about $6,000.00 and this does not include any mounting brackets, this was a too expensive solution. Also this OMT filtering would have to be in place, as the TX of the 2Watt system would be seen on the RX of the Web-sat system.

MTI in the USA in a press release of the 30th June 2000 for a KU band 1.2m collapsible antennas that was designed for receive only, a dish with transmit and receive capability was expected in 2001. The web site is at (http://www.mti-usa.com/) If this is to be used, it would have to pass Eutelsat specifications which would be cost prohibitive.

However it was noted whilst setting up a step by step procedure for lining up the mobile 1.2m dish, that the RX LNB of the Skylinks equipment gives a different spectrum to that from an universal TV LNB. In checking different satellite positions it was found that by moving the TV LNB to the left of the dish’s own horn it could pick up different satellites one of these being 19.2 East Astra (http://www.astra.com/) this is found to the west of the centre as the dish acts as a mirror. By securing a LNB at this spot it would allow staff to have access to the clear analogue channels of Sky Broadcasting on the spectrum meter. After further
research into what was on the Astra system an internet access service Astra-Net was investigated and a system was sourced from Mediasat (http://www.mediasat.ie/) this system works similar to Web-sat in that it has a low TX and a high down link from a satellite, but in the case of Astra-net the up link is a terrestrial connection to the web via any Internet Service Provider (ISP). Initial tests were done using a PSTN circuit for the ‘up link’ into the web and the off set LNB as the RX with good down load speeds standard browsing was not very fast but equal to 56Kbps rates even though the uplink was only 14.4Kbs. The next procedure was to use the Skylinx connection as the up-link and go out to the web via the SHB 128Kb and down load over the Astra-net.
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Figure 7-6  Network schematic for system

A comparison of Astra net down-load verses a leased line was performed with the following results.
Figure 7-7  Leased line download

Figure 7-7 shows a download from a realplayer site of 4.04 Mb 10.4 Kbps giving a throughput of above 80Kbps this was over a 128Kbps circuit with some browsing traffic and would be seen as a good flow over the Net.

Figure 7-8  Astra download

Using the Astra-net download the statistics were as follows
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Figure 7-8 shows a download from a realplayer site taking 3 minutes 12 seconds to download 12.7Mb at 68.1 Kbps giving a throughput of above 500Kbps.

7.4. **How the dish was modified**

The LNB was initially secured on a camera tripod, which allowed the LNB to move and then be secured in that position. Later the LNB was secured to a bracket, this bracket has to be adjustable as it is this movement that allows the LNB to be aligned.

![Modified 1.2m dish](image)

Having set the LNB on the new bracket signal strength of 110 out of a scale of 150 forty more than that achieved on the tripod.
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7.5. How the dual system works

As mentioned earlier the 1.2 meter dish is focused on a satellite at 7 East and over the equator. The second satellite is at 19.2 East and also over the equator. The 1.2m dish is positioned at say 9 West and 52 North.

Figure 7-10  Astra signal strength

Figure 7-11  Geographical location of satellites
There is approximate 1369Km between 7 East and 19.2 East the further one goes from the equator the angle at the receive dish reduces until one goes to 75 degrees from the equator, where geo-stationary satellites loose coverage. So at about 50 degree north the angle is small enough for me to access both satellites.

7.6. Video broadcast from remote site

One remaining requirement was the transmission of video from the remote to the main A&E station in CUH. Investigation into different existing ways and future ways of video transmission was carried out. Companies such as Motorola (http://www.motorola.com/) and Packetvideo (http://www.packetvideo.com/) are working on video over bandwidth of 14.4kbps to 768kbps using MPEG4. Motionmedia (http://www.mmtech.co.uk/) are developing a mobile videoconferencing phone for Orange telecom in the UK. As Mobile bandwidth increases from 9.6Kbps to 14.4Kbps with HSDC to 19.2Kbps duplex increasing to 28.8Kbps and with GPRS network starting at 20Kbps and increasing to a value of more than 100Kbps. All these developments show that even though bandwidth may be more accessible than in the past applications are being designed for small bandwidth also.

Having studied the requirements and speaking to Medical staff their main requirement for video is to get a general overview of a problem or location if more detail is required then a still digital photo can be taken and sent.

Having already used a web cast from a conference using both a terminal adaptor PCMCIA card it was noted that it put a lot of pressure on the laptop and increased the processing delay to 60 seconds. Using a router with an ISDN interface to the
same server decreased this to about 9 seconds. Thus the Ethernet interface is the preferred option.

To webcast from the vehicle Realplayer was run on a laptop and broadcast to a server in Aras Slainte, over the 56Kb satellite circuit. The broadcast was left to run for up to 7 hours with no problems.

Figure 7-12  Webcast

The first 7 minutes was recorded, the broadcast was accessible from any computer with realplayer both on the Southern Health Boards network or on the web by browsing to the URL rtsp://195.7.60.105/encoder/live.rm and was set up for 20Kbps (see Webcast manual).
7.7. A small PABX

As the space in the rear of the 4x4 is smaller than before a system smaller than the present one was required. The PABX should have Analogue connectivity local switching and VOIP connectivity. The solution chosen was the Nortel iremote (or 9150) this is a small rack mountable device (see Nortel 9150 set-up). Call were made and the quality was found to be almost toll quality.

Figure 7-13  VOIP Network schematic
The network configuration allows a user at the remote site to become an extension of the main site (Aras Slainte, in this case), and have all the functionality of the main system. Calls made over this system were at G.729A (8 kbps coding) the calls terminated on extensions in Aras Slainte, the Irish public network, Irish GSM network, the French GSM network and also on land lines in the Netherlands, all calls were regarded as being of excellent quality. The only problem was in making calls when the Webcast in progress. The web-cast uses a bandwidth of 20 Kbps plus overheads and if two calls are in progress the following bandwidth use is noted:

<table>
<thead>
<tr>
<th>Description</th>
<th>Bandwidth Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web cast 20 Kbps + 8 Kbps overheads</td>
<td>28 Kbps</td>
</tr>
<tr>
<td>Voice call 8 Kbps + 5 Kbps overheads</td>
<td>13 Kbps</td>
</tr>
<tr>
<td>Voice call 8 Kbps + 5 Kbps overheads</td>
<td>13 Kbps</td>
</tr>
<tr>
<td>Total Bandwidth used</td>
<td>54 Kbps</td>
</tr>
</tbody>
</table>

Table 7-2  Bandwidth use

Table 7-2 shows how close to the maximum bandwidth the Web cast and the two calls come. One of the calls begin to get clipped when there is a lot of back-ground noise at the vehicle. This background noise would be encoded by all three systems and force them to use the maximum bandwidth encoders try and send very small amounts of data during quite parts of conversation therefore saving bandwidth. On a normal conversation approximately half the time one or other of the speakers are silent.
The fact that the calls were of the quality achieved is an indication of the good quality of the transmission path as all who spoke either on single calls or on a call with another call in progress put the quality at GSM or better.
Putting it all into FECV2

Having tested all these technologies and equipment the next task was to integrate it all into the 4x4. The rear seats of the were removed and a bench was installed, new seats were installed giving room behind for an 19 inch rack in which the main technology equipment mounted. There is, from the bottom up, the UPS, the Satellite modem chassis, Nortel 9150, RJ45 Strip, the LAN Equipment (on its own self), the GSM Equipment also in a rack of its own and on top, the Radio equipment. All cables to and from the outside are connected to terminators in an inlet casing on the right rear panel. A pump up mast gives extra height for antennae and 12volt lighting if required (see Appendix FECV2 setup).

The vehicles

Figure 7-14   FECV’s
8. **The Future Satellite trends**

As the end user (the ones lucky enough to be within the reach of DSL from the local exchange) have speeds into the web from home that give a quicker responses than at work, these users will place a demand on the network/I.T managers to provide at least compatible if not faster service to both intranet and internet.

The structure of the web is as follows, the European backbone encompasses Amsterdam, Oslo, Paris and London, which are interconnected and also connected to the East and West. Depending on the ISP that a company uses the connection maybe two or three removed from the centre. Each ISP in the chain tries to over-subscribe its customer’s bandwidth to its Web access as much as they can get away with this creating a bottleneck.

![Schematic of Internet backbone](image)

**Figure 8-1 Schematic of Internet backbone**

The next bottleneck is the leased line from the company to the local ISP this gives a service to the LAN to which it in turn is connected. If there are a number of connections in series within the corporate WAN, beyond this LAN there are new
potential bottle-necks both in Bandwidth and in delay terms. This may lead to inconsistency in performance and confusion, as to whether it is the corporate network that is slow, or the delay is on the Internet. If a company uses network management software these delays can be identified and localised.

Satellite services may well be the answer to the above problem, at a recent broadband Multi Media conference in Bologna Italy. Mr Giuliano Berretta Director General & Chief Executive Officer of Eutelsat stated that satellites can provide the reach where DSL will find difficult. A number of solutions were proposed:

- The use of the Eutelsat D160 or D2000 products
- DVB services
- The use of unstable older satellites

The Eutelsat D160 service
This is the service at present being utilised by the FECV, by installing a new card in the chassis of the indoor system and by installing an antenna system in an ISP premises as close to the backbone of the Internet as possible.

Then the remote site can transmit, (in our example at 56kbps), the return path can have a bandwidth of up to 2Mbps. This will allow bursts of up to 2Mbps but this is dependant on the number of users browsing at that time. As it is the one pipe to all remote systems the perceived response is the same for all sites.
The Eutelsat D2000 service

The D2000 system is similar in design to the D160 but has no network management system. The system uses dishes of 1.8m and 2.4m with a power of 16W this produces a bandwidth in the region of 2Mbps the system can be coupled to produce a transmit bandwidth of up to 8Mbps. The remote site can have two configurations one as the above where they transmit into a virtual cloud with the Linkway 2000 boxes routing the IP packets to the appropriate station. The other configuration was proposed to Eutelsat by the Southern Health Board, this is where the remote site does not have a transmit power amplifier (as seen earlier is one of the dearer parts of the VSAT station). The uplink to the Internet would be via the terrestrial network and the return path can burst up to 8Mbps, with the arrival of the Linkway 2100 speeds up to 15Mbps will be expected.

In summary the D160 is suitable for corporate networks with small data rate requirements in a dial up type access for both voice and data. All calls are set-up via the Network Management Station in Fuchino Italy. Where the D2000 is more efficient is when it is used in a total IP structure as each node does its own routing and works equally in a mesh or point-to-point configuration.

The DVB solution is similar to the Astra data service mentioned earlier, one of these is proposed by Nera. This system has a DVB central station, which converts the Ethernet, based IP packets into the DVB format and also has a return channel capability. The output of the gateway is in the region of 35 to 45 Mbps with a back channel of 512Kbps to 2Mbps using Turbo coding and dependant on the size of the dish, geographical advantage and the power of the transmitter.
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The remote station has been revised in the Astra system in that instead of a card in a computer the indoor unit has an Ethernet interface which connects to the user’s LAN and F connectors to connect to the antenna. The size of the router is similar to a Cisco 2500 series. This solution is suitable for large corporate networks using Intranet and Internet style applications.
The third solution uses the fact that as satellites become older they become unstable and not true geo-stationary. Such satellites can be used by having an antenna that is able to track the deviation of the satellite. This type of earth station is more costly than the norm but the cost of the space segment can be as much as 70% of the stable price. This solution is suitable for campus sites requiring large bandwidth into the Internet backbone.
A fresh look at the provision of bandwidth to a health agency
9. Campus Networks that utilise existing cabling

9.1. Introduction

In a time in Ireland where there is much talk about unbundling the local loop.\(^1\) Companies with large campus sites should be looking at using this existing copper as an asset rather than as a bundle of old wires terminated in a corner of the buildings in which the phone system works. The Southern Health Board, as mentioned earlier, has sites with a large number of separate buildings. One of these is St Finbarrs Hospital in Cork city, a site with more than fifty buildings or blocks. All of the buildings have telephone connectivity from the main PABX room in the middle of the campus. Some of these buildings are old, as they were part of the old acute hospital services for the Cork city before the building of Cork University Hospital. As some of the old ward areas are not used any more staff may be working in office space, which used to support the wards spread throughout the buildings in a haphazard way.

The data network in the campus has a 2Mbps link to the rest of the Southern Health Boards data network and there are small isolated LANs throughout the campus. The phone system is connected to the Southern Health Board’s Voice network by a 2Mbps circuit and to the public network by both a 2Mbps circuit and PSTN lines.

\(^1\) The local loop is the distance between the nearest exchange and the customers premises, normally copper but now can also refer to radio access to the nearest mast as WLL (wireless in the local loop).
Figure 9-1  St Finbarrs Campus
Figure 9-2  Cork University Hospital Campus
In contrast with St Finbarrs, Cork University Hospital consists of only four separate buildings. The main complex has a number of wiring closets linked by fiber and has CAT5 cable to the desktop.

To utilize copper that already exists, an understanding of the principles of telephone cables and the rational underpinning their design has to be carried out, then the information gathered can be used to extend the networks reach.
9.2. Learning from the past

The basic connection medium in Telecommunication is the copper wire which dates from the days of the manual switchboard, where the customer (subscriber or sub as they were then known) cranked a handle on the side of the phone. This generated an alternating current (AC), which dropped an indicator in the switchboard. In most areas the subs loop was an open pair of wires (not insulated), but in locations like Dingle Co Kerry there was an earth return with one wire per customer and an earth rod at each side to form the electrical circuit. This wire was made of copper and its quality was described in terms of pounds per mile of the wire e.g. one wire a mile long weighed 70 lbs. Later a mixture of Cadmium and Copper (cad copper)\(^2\) which had a higher tensile strength than pure copper was used and it had a breaking strain of 5 times its lbs weight per mile as opposed to copper at 3 times. Trunk cable could be 150 lbs per mile and the pairs of open wires could, up to recently, be seen on the sides of railways and

\(^2\) Table of loop resistance and sizes

<table>
<thead>
<tr>
<th>Loop res in ohms</th>
<th>Wire size in mm</th>
<th>Wire size in lbs/mile</th>
<th>Loop res in ohms</th>
</tr>
</thead>
<tbody>
<tr>
<td>275 0.4 cu</td>
<td>4 cu</td>
<td>0.32</td>
<td>2.5</td>
</tr>
<tr>
<td>168 0.5 cu</td>
<td>6.5 cu</td>
<td>0.7</td>
<td>12.5</td>
</tr>
<tr>
<td>110 0.63 cu</td>
<td>10 cu</td>
<td>USA AWG</td>
<td></td>
</tr>
<tr>
<td>55 0.9 cu</td>
<td>20 cu</td>
<td>0.5</td>
<td>24</td>
</tr>
<tr>
<td>27.5 1.25 cu</td>
<td>40 cu</td>
<td>0.4</td>
<td>26</td>
</tr>
<tr>
<td>33 1.25 cad cu</td>
<td>40 cad cu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 1.7 cad cu</td>
<td>70 cad cu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7.4 2.5 cad cu</td>
<td>150 cad cu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>66 0.9 cad cu</td>
<td>20 cad cu</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

loop resistance of copper = length of circuit in yds / weight of one conductor in lbs per mile
loop resistance of cad copper = (that of copper) * 1.2
were mainly of copper because of its low electrical resistance. All that is left now are the poles with the many arms and spindles (the white insulators).

Figure 9-3 Pole with arms and spindles
9.3. Problem and solutions

As these wires travelled from one exchange the wires were subject to inductive disturbance, which would interfere with speech if preventive measures were not taken.

\[
\text{Current } X > Y
\]

**Figure 9-4 Electromagnetic inductions**

The interference is both electrostatic and electromagnetic but the effect of the latter is greater. Electromagnetic induction is the EMF induced in one wire by a current flowing in another this is in the opposite direction. Wire A has a current flowing as shown in figure 8-4, this induces a current X in B and a current Y in C as the distance from A to B is less than A to C, X is larger than Y if the pair is connected in a circuit a current will flow between B and C this will be in sympathy with the current changing in A. If B and C were the same distance from A this would
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not happen as the same EMF would be generated in both. To achieve this in theory what was needed was for exactly half the circuit to have A near B and the other half near C. Twisting the wires regularly rather than at half way can also achieve this, as the strength of the signal in A may be reducing as we move away from its source.

In practice this was achieved in two ways:

- Transposition Cross where the pair is crossed from spindle to spindle over a distance of 8 miles.

![Code Plan of Transposition Poles: 1/4 mile intervals.](image)

**Figure 9-5 Transposition Cross**
The Twist System where the pair are at diagonals of a square and rotate every pole a rotation every 4 poles.

![Twist System Diagram](image)

**Figure 9-6  Twist system**

(Fig 8-5 and 8-6 were extracted from P&T training manuals for Technician Trainees 1980)

The next development was multi-core cable and instead of air the dialectic was paper (a very good insulator when dry), the cable was covered by lead. To join these cables the wires were nib jointed and covered by paper sleeves the wires were identified by the number of rings of different colours on the paper covering, and these markings were spaced out so as keep the dielectric constant over the length of the cable. The cable was nib jointed and covered by paper sleeves, then the lead was plumbed and soldered to form a waterproof seal.

With the manufacture of plastic Polyethylene and PVC Polyvinyl chloride a more damp proof insulator was available and used the number of pairs also increased as did
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the ability to twist the pairs themselves and as a group to form quads. A repetitive
colour code came into being with primary colours and secondary colours. This can be
repeated over and over as each quad is wrapped in a coloured tape, which is tied back
as a cable is fanned out.

Taking a 25 pair cable as an example, not alone does the change of voltage in one wire
effect one pair it affects the other 49 wires. Let us now examining these effects within
the cable environment and see how they have been reduced. In the Dingle single wire
scenario, again using a single cable we have what is called Unbalanced Transmission.

---

1 Nib the wrapping of the bare wires together, by twisting them and then cutting the loose wire.

<table>
<thead>
<tr>
<th>Pair number</th>
<th>A wire</th>
<th>B wire</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>White</td>
<td>Blue</td>
</tr>
<tr>
<td>2</td>
<td>Orange</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Green</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Brown</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Slate</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Red</td>
<td>Blue</td>
</tr>
<tr>
<td>7</td>
<td>Orange</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Green</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Brown</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Slate</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Black</td>
<td>Blue</td>
</tr>
<tr>
<td>12</td>
<td>Orange</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Green</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>Brown</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Slate</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>Yellow</td>
<td>Blue</td>
</tr>
<tr>
<td>17</td>
<td>Orange</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Green</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>Brown</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>Slate</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>Violet</td>
<td>Blue</td>
</tr>
<tr>
<td>22</td>
<td>Orange</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>Green</td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>Brown</td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>Slate</td>
<td></td>
</tr>
</tbody>
</table>
Figure 9-7  Noise interference

In unbalanced transmission, or one-side-grounded transmission, one of the two conductors making up the pair is grounded at both ends. This type of transmission works well at low data rates for short distances in noise free environments. However, noise can be picked up from external sources such as the ballast used to control fluorescent lights, mobile phones and motors. The receiver interprets this noise as data and this causes errors.

Traditionally the way to avoid this is to use shielded cables, with the shield grounded on both ends, whereby reducing the cable's susceptibility to external noise.

A much less expensive way of avoiding external interference is to use a balanced transmission system, which need two wires. In balanced transmission, small transformers or "Baluns' are used to isolate the cable from the electronics and only pass the difference of the signal onto the cable.
Figure 9-8 Noise balancing

The two conductors of the pair carry the opposite but equal transmitted signal. The sum of the signals being emitted is ideally zero resulting in no emissions. The two conductors of a pair deliver the receive signal the data plus the noise the noise cancels out as can be seen in figure 8-8.

Radiated emission, or the amount of energy that radiates from cable, is a concern if the radiated emission (referred to as Electro Magnetic Interference (EMI) of a system) is excessive. It may cause interference to other services, such as broadcast television. In a balanced system, where one conductor of a pair has the exact opposite data signal from the other conductor, the field generated by one conductor is virtually cancelled by the field generated by the other conductor. This is because the two conductors of a pair are so close to each other and in a system that uses well balanced electronics and well balanced cable, the EMC limits, and maximum emission allowances can easily be met.

The amount of noise picked up by one conductor of a pair is about the same as the amount of noise picked up by the other conductor. The twisting or a pair, improves this even more, thereby virtually guaranteeing that the amount of noise picked up by each
conductor is virtually identical. The Balun at the interface to the receiver only allows
the difference of the signal to pass through. The differential Signal data signal is let
into the receiver reproducing the original signal. Therefore, only the desired data signal
is passed through and the undesired noise is rejected.

9.4. Attenuation

Another problem for the signal is attenuation, which is the loss or diminishing of a
signal when it passes through a transmission medium. Loss occurs in any type of
transmission medium. The effect of attenuation is important because this primarily
determines the maximum distance by which two devices can be separated. Attenuation
in copper wire is caused by two factors.

• Copper loss, which is unavoidable and the same for all cables of the same
gauge and resistance.

• Dielectric loss, or dissipation, due to the insulation and jacketing materials used
on the conductors and the cable.

Minimising the dissipation loss of the insulating and jacketing materials is important
so as to minimise the cable's attenuation, the dissipation factor being a relative
measurement of a material's loss. Of the typical materials used in cables, the two
optima are Polyethylene and Teflon.

Attenuation is usually expressed in dB per unit length (X dB/1,000 m) and is a measure
of how much a signal is weakened or reduced in amplitude as it travels down a cable.
The lower the number therefore the lower the attenuation.
9.5. Crosstalk

In a four-wire circuit (two pair), one pair is used to transmit data from one device to another, the other pair is used to receive data from the far end. A four-wire circuit is used here to demonstrate interference or cross talk.

Figure 9-9 Crostalk from one cable pair to another

Crosstalk is the amount of signal coupled into other conductors. This is measured in dBs. The lower the value of Crosstalk of a cable, the better the cable performance. In outdoor cables the main causes of crosstalk are capacitive imbalance, resistive imbalance, inductive coupling, wire-to-wire contacts and low insulation values. As most outdoor cables are jointed this can also cause crosstalk as well as attenuation. In internal cabling such as cat 5, there are no joints, reducing the chances of crosstalk. Cat 5 cable is also manufactured to higher standards than the outdoor cable, again reducing interference.

Near End Crosstalk (NEXT) refers to the undesired coupling of signals from the transmit pair onto the receive pair on the same end. NEXT isolation is expressed in dB and is a measure of how well the pairs in a cable are isolated from each other.
Far End Crosstalk (FEXT) refers to the undesired coupling of signals from the transmit pair onto the receive pair, this affects the cable similar to NEXT but as it is measured at the other end has undergone the attenuation of the line. FEXT isolation is also expressed in dB. For most applications however, the NEXT isolation is the dominant factor and its values are more important.

One circuit is hardly ever on its own, in reality each and every circuit in the cable affects all other circuits, and for Crosstalk it is no different. Take 3 circuits each active with the same end equipment, one side (the RHS) will have NEXT from the local transmit and FEXT from the remote transmits. Taking each circuit separately and discussing its effects on circuit Number 1. (see figure 8-10)

Circuit 1 on itself NEXT from pair ‘a’ Tx to pair ‘b’

FEXT as mentioned in this case can be ignored.

Circuit 2 and 3 on Circuit 1

Pair ‘a’ effects both pair ‘a’ and ‘b’ of circuit 1 but as the signal on ‘b’ is weaker (from attenuation of the line) the noise in proportion to the signal present will be higher.

Pair ‘b’ also effects pair ‘a’ and ‘b’ of circuit 1 but the signal which in this case started at the remote (LHS) is being attenuated in proportion to the signal on pair ‘b’ so again FEXT is not as important as NEXT.
Figure 9-10  Crosstalk from adjacent pairs

The best way to achieve good Crosstalk performance is to use short tight twists on the cable pairs. The Crosstalk performance of a cable is mainly determined by the twist scheme. If long twists are used, the conductors from different pairs tend to nest together or intrude inside an adjacent pairs’ cylinder. In the case of short twists, because the location of the pair rotates so fast within the cylinder, the conductors from the other pairs are prevented from invading the pair’s cylinder. Thereby pair separation is increased and the distortion of the ideal helical shape of the twisted pair is decreased, both effects result in significantly improved Crosstalk performance. In short good design of the cable, which is installed, to a high standard and maintained in good condition will provide a reduction in cross talk and general good performance over the
life of the cable.

9.6. **Cable Structure and Characteristics**

9.6.1. **Loading Coils**

Long lines and inter exchange trunk lines sometimes had a high attenuation between them and as the total maximum attenuation on a call\(^5\) is set, this lead to problems. The way of reducing this attenuation is by putting inductive coils of 88mHenrys at spacing of 1.83 Km (2000Yds). They changed the characteristics of a line from relationship between attenuation and frequency to one of a low pass filter.

For higher quality circuits 16mH coils spaced at distances of 915meters were used.

<table>
<thead>
<tr>
<th>Loading of 88mH</th>
<th>Cut off frequency of 3920 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loading of 44mH</td>
<td>Cut off frequency of 5470 Hz</td>
</tr>
<tr>
<td>Loading of 22mH</td>
<td>Cut off frequency of 7640 Hz</td>
</tr>
</tbody>
</table>

In order to get best results the spacing between coils had to be kept within ±18 meters.

![Figure 9-11](image)

\(^{5}\) call attenuation dBs was more important in days before digital communication, levels of loss for national and international calls were expected.
9.6.2. **Cable layout**

The above solved the long hauling of voice traffic but in the 1970's to early 1990's Telex machines were in every local Garda station (Fax machines even if present could not be used for legal documentation). The Telex puts a voltage swing on the line of ±80V, these pulses or marks and spaces were known to caused interference problems to other data circuits. This problem was be solved in a simple way using the make up of the cable to solve the problem.

As mentioned each bundle of pairs add up to 25 but what happens when we require a cable of 300 or even 4200 pairs. An example of this is seen in figure 8-13 (an extract from BICC outside voice and data technical information (http://www.biccpprotenox.co.uk/). From the layout if telex uses one bundle, transmit and receive pairs can be separated by picking pairs in different bundles as the transmit signal strength is the same per bundle the interference is reduced.

![Color Code Chart](image)

**Figure 9-12** 25 pair colour code and bundle colour code
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9.7. Cable infrastructure

Nearly all Telecommunication cables today are manufactured to standards and colour codes similar to figure 8-12 and 8-13. These codes making the job of terminating or even counting pairs a standard procedure. Cables can be from 1 pair to 1,000 pairs and are run in nearly every building where there is a phone system. At the end of each cable there is a termination point from where cables can distributed. The way this is done has changed over the years but the principle is the same.

Exchange style MDF
Wire rapped and soldered

Siemens Punch down block

Figure 9-14 Termination blocks
In the old blocks the wires were stripped, wound about the tags and soldered into place. This practice does not cause any problems in new blocks but with re-terminations the amount of excess solder grew and the possibility of bad connections increased. This type of fault is known as dry joint, where the solder did not melt enough to create a good electrical connection. The cable was made off on one side (say the left hand side) then the pairs were jumpered to the required line position, or another cable, as required from the right hand side.

Figure 9-15  The termination of jumpers on tags

In the newer block the cable is brought in from the side and terminated on the top

Figure 9-16  Krone blocks and jabber
connectors, the jumpers are terminated on the bottom. Termination in this case is by impact tool (Jabber) that pushes the wire between teeth in the contacts and breaks the insulation giving the electrical contact.

9.8. **Utilising the cable for more than voice**

Telecommunication equipment uses the bandwidth 300 Hz to 3,400 Hz, which contains most of the human voice power spectral density. As bandwidth requirements increased coaxial cable was used to deliver data services to the desktop. Initially from Mainframes such as IBM 3270 running at 2.36 Mbps, other network speeds were

- IBM PC networks 2Mbs
- IBM Token ring networks 4Mbs
- Datapoint Arcnet 2.5Mbs
- Appletalk 230Kbs
- HarrisNet 1.25 – 10Mbs
- Novell Netware 4/10Mbs
- Proteon ProNet 8 – 80Mbs

(Above speeds from Harris Networking Explained 1989).

Later LAN's using the Ethernet protocol ran at speeds of 10 Mbps, which was more than a pair of wires could carry without errors for further than a few meters.

Coaxial networks are of two forms:

- Thick net (10BASE5)
  
  - The maximum length of a segment is 500 meters.
  
  - The cable is made up of 50 Ω high quality coaxial cable.
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- A maximum of 2 IRL (InterRepeater Links) is allowed between devices; the maximum length of cable is 2.5 km.

- Devices attach to the backbone via transceivers.

- The minimum distance between transceivers is 2.5 meters.

- The maximum length of a transceiver cable is 50 meters.

- Up to 100 transceiver connections can be attached to a single segment but at strict 2.5m intervals, which are marked on the cable.

- Both ends of each segment should be terminated with a 50-ohm impedance.

- Only one end of each segment must be grounded to earth.

- Thin net (10BASE2)

  - The maximum length of a segment is 185 metres.

  - The cable is made up of 50 Ω low quality coaxial cable.

  - A maximum of 2 IRL (InterRepeater Links) is allowed between devices; the maximum length of cable is 925 meters.

  - Typically, devices use Ethernet network interface cards (NICs) with built-in BNC terminated transceivers, so connections can be made directly to the ThinNet cable.

  - Devices are connected to the cable with T-connectors, which must be plugged directly into the card. No cable is allowed between the T and
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the card. Workstations are daisychained with an "in-and-out" cabling system.

- The minimum distance between T-connectors is 0.5 meters.

- If the interface card does not have its own built-in BNC terminated transceiver, a BNC terminated transceiver and transceiver cable are required. The maximum length of a transceiver cable is 50 meters.

- Up to 30 connections can be attached to a single segment.

- Both ends of each segment should be terminated with a 50Ω impedance.

- One end of each segment should be grounded to earth.

It is the daisy chaining of devices and the need to have the end terminated that causes the biggest difficulties. If the cable is broken or becomes unterminated at any point then the segment is out of order, this made the removing or adding of devices difficult.

To solve this the segments were collapsed into a hub from which each cable radiated in a star formation to the desktop.

(10BASE-T)

- There are two versions of Ethernet over unshielded twisted pair: 10BASE-T (the standard) and its predecessor UTP.
10BASE-T and UTP segments can coexist on the same network via a transceiver and transceiver cable or converter when each hub is attached to a common segment.

- The cable used is 22 to 26 AWG unshielded twisted pair (standard telephone wire), at least Category 2 with two twists per foot. Category 3 or 4 is preferred. Category 5e supports 100BASE-T (Fast Ethernet) and is recommended for all new installations.

- Workstations are connected to a central concentrator ("Hub" "Switch") in a star configuration.

- The maximum segment distance from concentrator to node is 100 meters.

- The maximum number of devices per segment is two: the hub port and the 10BASE-T or UTP device.

As the name suggests the twist is the important point to remember and the distance of 100 meters.

The following is a list of categories and performances:

- **Category 1** = No performance criteria
- **Category 2** = Rated to 1 MHz (used for telephone wiring)
- **Category 3** = Rated to 16 MHz (used for Ethernet 10Base-T)
- **Category 4** = Rated to 20 MHz (used for Token-Ring, 10Base-T)
- **Category 5** = Rated to 100 MHz (used for 100Base-T, 10Base-T)
- **Category 5e** = Rated to 100 MHz (used for 100Base-T, 10Base-T). This has higher specifications for NEXT and FEXT as well as Return loss than CAT5
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- Category 6 = With the standards bodies but expected to be rated to 250 MHz (used for 1000Base-T, 100Base-T, 10Base-T)

On opening a Cat 5 cable four pairs of the standard cable code can be seen. The pairs (white blue, blue) and (white brown, brown) have less twists than the pairs (white orange, orange) and (white green, green) as can be seen in figure 8-17.

Figure 9-17  CAT 5 cable fanout

It is the tighter twists and the wrapping of the pairs on themselves and compliance with the wiring standards, that allows the CAT 5 cable to be used for speeds up to 100Mbs over distances of 90m.

Figure 9-18  RJ45 Connectors and jack
These Cat 5 cables are terminated on RJ45 connectors, in the case of patch leads from outlets to equipment, and on punch down tags on Jacks within the outlet or RJ 45 wiring panel.

Figure 9-19  Rear of wall socket, patch panel and 110 jabber

Category 5 cabling pin outs are standardised to two standards:

- Standard EIA/TIA T568A  (also called ISDN, previously called EIA)

<table>
<thead>
<tr>
<th>Pin</th>
<th>Wire</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>T3</td>
<td>1</td>
<td>White/Green</td>
</tr>
<tr>
<td>R3</td>
<td>2</td>
<td>Green</td>
</tr>
<tr>
<td>T2</td>
<td>3</td>
<td>White/Orange</td>
</tr>
<tr>
<td>R1</td>
<td>4</td>
<td>Blue</td>
</tr>
<tr>
<td>T1</td>
<td>5</td>
<td>White/Blue</td>
</tr>
<tr>
<td>R2</td>
<td>6</td>
<td>Orange</td>
</tr>
<tr>
<td>T4</td>
<td>7</td>
<td>White/Brown</td>
</tr>
<tr>
<td>R4</td>
<td>8</td>
<td>Brown</td>
</tr>
</tbody>
</table>
And Standard EIA/TIA T568B (also called AT&T specification, previously called 258A)

<table>
<thead>
<tr>
<th>Pin</th>
<th>Wire</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2</td>
<td>1</td>
<td>White/Orange</td>
</tr>
<tr>
<td>R2</td>
<td>2</td>
<td>Orange</td>
</tr>
<tr>
<td>T3</td>
<td>3</td>
<td>White/Green</td>
</tr>
<tr>
<td>R1</td>
<td>4</td>
<td>Blue</td>
</tr>
<tr>
<td>T1</td>
<td>5</td>
<td>White/Blue</td>
</tr>
<tr>
<td>R3</td>
<td>6</td>
<td>Green</td>
</tr>
<tr>
<td>T4</td>
<td>7</td>
<td>White/Brown</td>
</tr>
<tr>
<td>R4</td>
<td>8</td>
<td>Brown</td>
</tr>
</tbody>
</table>

Pins 1, 2, 3 & 6 are used for data while pins 4 & 5 are used for telephony and pins 7 & 8 for power feed. (T and R refer to Tip and Ring from the days of manual switchboards when the plugs that connected calls had a Tip, a Ring (A and B wire) and a Sleeve, which was earth potential). T568B is the standard used by the Southern Health Board.

A subset of this T568B is

Standard EIA 356A (a 3-pair cable leaving out the brown pair)

<table>
<thead>
<tr>
<th>Pin</th>
<th>Wire</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2</td>
<td>1</td>
<td>White/Orange</td>
</tr>
<tr>
<td>R2</td>
<td>2</td>
<td>Orange</td>
</tr>
<tr>
<td>T3</td>
<td>3</td>
<td>White/Green</td>
</tr>
</tbody>
</table>
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- R1 4 Blue
- T1 5 White/Blue
- R3 6 Green

When connecting two end devices such as computers together a crossover cable can be used.

Cross Over cable Pin outs:

<table>
<thead>
<tr>
<th>Pin</th>
<th>Wire</th>
<th>Colour to</th>
<th>Pin</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>T2</td>
<td>1</td>
<td>White/Orange</td>
<td>3</td>
<td>White/Green</td>
</tr>
<tr>
<td>R2</td>
<td>2</td>
<td>Orange</td>
<td>6</td>
<td>Green</td>
</tr>
<tr>
<td>T3</td>
<td>3</td>
<td>White/Green</td>
<td>1</td>
<td>White/Orange</td>
</tr>
<tr>
<td>R1</td>
<td>4</td>
<td>Blue</td>
<td>5</td>
<td>White/Blue</td>
</tr>
<tr>
<td>T1</td>
<td>5</td>
<td>White/Blue</td>
<td>4</td>
<td>Blue</td>
</tr>
<tr>
<td>R3</td>
<td>6</td>
<td>Green</td>
<td>2</td>
<td>Orange</td>
</tr>
<tr>
<td>T4</td>
<td>7</td>
<td>White/Brown</td>
<td>8</td>
<td>White/Brown</td>
</tr>
<tr>
<td>R4</td>
<td>8</td>
<td>Brown</td>
<td>7</td>
<td>Brown</td>
</tr>
</tbody>
</table>

Now that we have agreed on a standard, next we must look at how the LAN uses the cable:

- Ethernet 10Base-T uses pairs 2 and 3 (pins 1-2, 3-6)
- Ethernet 100Base-T4 uses pairs 2 and 3 (4T+) (pins 1-2, 3-6)
- Ethernet 100Base-T8 uses pairs 1,2,3 and 4 (pins 4-5, 1-2, 3-6, 7-8)
- Token-Ring uses pairs 1 and 3 (pins 4-5, 3-6)
- 100VG-AnyLAN uses pairs 1,2,3 and 4 (pins 4-5, 1-2, 3-6, 7-8)
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- ATM 155Mbps uses pairs 2 and 4 (pins 1-2, 7-8)

The colour of label used on a cross connect field identifies the field's function. The cabling administration standard (CSA T-528 & EIA-606) lists the colours and functions they are used for:

- **Blue** Horizontal voice cables
- **Brown** Inter building backbone
- **Grey** Second-level backbone
- **Green** Network connections & auxiliary circuits
- **Orange** Demarcation point, telephone cable from Central Office
- **Purple** First-level backbone
- **Red** Key-type telephone systems
- **Silver / White** Horizontal data cables, computer & PBX equipment
- **Yellow** Auxiliary, maintenance & security alarms

Another standard is where the colours are made off from the blue to brown from the middle out as shown

- **Standard (USOC)**

<table>
<thead>
<tr>
<th>Pin</th>
<th>Wire</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>T4</td>
<td>1</td>
<td>White/Brown</td>
</tr>
<tr>
<td>T3</td>
<td>2</td>
<td>White/Green</td>
</tr>
<tr>
<td>T2</td>
<td>3</td>
<td>White/Orange</td>
</tr>
<tr>
<td>T1</td>
<td>4</td>
<td>White/Blue</td>
</tr>
</tbody>
</table>
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- R1 5  Blue
- R2 6  Orange
- R3 7  Green
- R4 8  Brown

9.9. Structured wiring and its interoperability

RJ 11 or RJ12 (used for PSTN) connectors fit into RJ45 sockets if the socket is used for voice or modem connectivity. These connectors are smaller versions of the RJ45 connector and are made up of 6 pins. But some times only 2 wires are connected.

Figure 9-20  RJ 11 socket

In the RJ 11 connector one pair is used pins 3 and 4 (Red and Green) these are its centre pair and can connect to pins 4,5 on the RJ45 (Blue, White) by means of a straight through RJ 11 to RJ 11 cable. ISDN also uses two wires, Basic Rate Interface (BRI) is provided by the carrier from telephone exchange to the customer premise on a two wire U-BUS RJ-45 connector on the centre pins 4-5.
The Southern Health Board uses ISDN BRI U Bus configuration to extend the carriers U Bus reach within the campus rather than converting to S Bus and then using 2 pairs (as seen later). Three U Bus connections can be transferred on one CAT5 cable facilitating 384Kb video conferencing to any location within a structure-wiring closets reach.

In hospital settings where inter closet connectivity is via fibre it is important to have copper cables coming from the PABX or Carrier's interconnection with the building to each closet. At the video conferencing unit the three NT1 (a device that converts 2 wire U Bus ISDN to 4 wire S Bus) units are wired from the back of a socket. This allows the configuration to work by patching the U Bus at the closet and at the outlet by standard patch leads. Note the voltage on the U bus can be 80 to 90 volts and would damage other devices (computer network cards) if plugged into the outlet carrying the U bus interface.
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Figure 9-21 Delivery of U Bus using structured wiring

The S Bus mentioned above as needing a minimum of 4 wires to be delivered

ISDN S/T Bus Pin out

- RJ45 Plug for ISDN S/T bus
  - 1 N/C
  - 2 N/C
  - 3 White/Green Receive +
  - 4 Blue Transmit+
  - 5 White/Blue Transmit-
  - 6 Green Receive -
  - 7 White/Brown -48VDC (optional)
  - 8 Brown -48VDC Return (optional)
The above ISDN S bus wiring conforms to CCITT I.431 and is similar to an American way of delivering 2 PSTN lines to a socket, i.e. RJ12 with line one on pin 4 and pin 5 and the second line using pin 3 and pin 6.

Enterasys (formally Cabletron) have developed a modification to the wiring standard to deliver both 10Mb to the Roamabout (Wireless LAN) base stations, which is used by the Southern Health board.

- RJ45 Plug for Roamabout wireless LAN device
  - 1 Data
  - 2 Data
  - 3 Data
  - 4 Power
  - 5 Power
  - 6 Data
  - 7 Power
  - 8 Power

This varies from the standard of having telephony on pins 4 and 5 but by doing this it can be used on the EIA356A standard. The power supply is 24V DC and 400mA and is polarity independent.
Figure 9-22  Cabletron wireless LAN remote power module

Another use for CAT5 cabling is the transfer of 2Mb G703 information from in the case of the Southern Health Board from 8Mb radio links, the terminal equipment present G703 75 ohm 2Mb dual coaxial interface. To transfer these circuits to the PABX room an adaptor from 75 ohm to 120 ohm is used the RJ connector is used as follows.

- RJ45 Plug for 2Mb 120 ohm transmission
  - 1  Data Transmit
  - 2  Data Transmit
  - 3  GND Earth
  - 4  Data Receive
  - 5  Data Receive
  - 6  GND Earth
Another product that utilises CAT5 cabling is a cable splitter that utilises the cable as follows:

- RJ45 Plug for Black Box Data splitter
  - 1 Data 1
  - 2 Data 1
  - 3 Data 1
  - 4 Data 2
  - 5 Data 2
  - 6 Data 1
  - 7 Data 2
  - 8 Data 2
Figure 9-24  Dual data outlet cable doubler

This gives an extra data point, but using pairs for a second circuit that have been designed for telephony and power feed.

9.10. Voice and Data integration on CAT5

The two can be integrated within buildings by cabling from the outlets to a central wiring rack as standard. The active data equipment and the phone systems extension interface are mounted on the same rack by using RJ45 cables any outlet can be fed by any telephone extension or any data port. Coloured cables to EIA-606 standard help staff identify voice from data.
Wiring of Closet
Outlets 1 to 48 can be used for either Voice or Data.

By the use of a modified cable or connector the integration can be complete where each outlet is both Data and Voice this be seen below

Figure 9-25   Wiring closet for voice and data

Figure 9-26   Schematic of modified cable

At the Wiring closet the RJ11 end is plugged into the telephone output of the PABX the RJ45 with wires 1,2,3,6 terminated is connected to the data hub or switch while the remaining RJ45 is connected to the outlet wiring panel strip. The latter is plugged into
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the wall outlet at the client end the RJ11 connects to the phone and the other RJ45 to
the PC.

This allows for the use of existing outlets for voice and data and saving on new outlets,
less cable is used and fewer outlets are needed at the wiring closet.

Figure 9-27  Modified cable

At the hub one cable the data is made off on wires 1,2,3 and 6 while the voice is made
off on both 4 and 5 for voice and wires 7 and 8 are used to strengthen the crimp, four
wires are connected from either cable. At the room side the data cable is made off as
above while a flat cable is made off on pins 4,5,7 and 8, this cable has an RJ11
terminated to connect to a phone or fax.
The cost saving on an installation is as follows:

9.11. Test Case 1

<table>
<thead>
<tr>
<th>Material Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 x Drums of Cat 5 cable</td>
<td>£432.00</td>
</tr>
<tr>
<td>1 x 48 port Cat5 patch panel</td>
<td>£160.00</td>
</tr>
<tr>
<td>2 x cable management</td>
<td>£45.00</td>
</tr>
<tr>
<td>24 x Cat5 RJ45 Twin outlets</td>
<td>£240.00</td>
</tr>
<tr>
<td>24 x Back boxes</td>
<td></td>
</tr>
<tr>
<td>Trunking and conduit</td>
<td></td>
</tr>
<tr>
<td>Patch leads 1m RJ45 to RJ45 x 48</td>
<td>£144.00</td>
</tr>
<tr>
<td>Patch leads 1m RJ11 to RJ11 x 48</td>
<td>£96.00</td>
</tr>
<tr>
<td>Sundries (Clips, ties, etc.)</td>
<td></td>
</tr>
</tbody>
</table>

Labour: £3315.00

Total: £4563.48

Table 9-1 Cabling test case 1
9.12. Test Case 2

Total No. of runs 24
Average length per run 50 meters
Twin outlets 24

**Materials**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x Drums of Cat 5 cable</td>
<td>£216.00</td>
</tr>
<tr>
<td>1 x 24 port Cat5 patch panel</td>
<td>£ 80.00</td>
</tr>
<tr>
<td>2 x cable management</td>
<td>£ 45.00</td>
</tr>
<tr>
<td>24 x Cat5 RJ45 Single outlets</td>
<td>£168.00</td>
</tr>
<tr>
<td>24 x Back boxes</td>
<td></td>
</tr>
<tr>
<td>Trunking and conduit</td>
<td></td>
</tr>
<tr>
<td>Patch leads 1m RJ45 to RJ45 x 24</td>
<td>£72.00</td>
</tr>
<tr>
<td>Patch leads 1m RJ11 to RJ11 x 24</td>
<td>£48.00</td>
</tr>
<tr>
<td>Sundries (Clips, ties, etc.)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£859.75</strong></td>
</tr>
</tbody>
</table>

**Labour**

<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installation</td>
<td>£2821.00</td>
</tr>
<tr>
<td>Termination</td>
<td></td>
</tr>
<tr>
<td>Testing</td>
<td></td>
</tr>
<tr>
<td>Labelling</td>
<td></td>
</tr>
<tr>
<td>Documentation</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>£2821.00</strong></td>
</tr>
</tbody>
</table>

**Table 9-2 Cabling test case 2**

<table>
<thead>
<tr>
<th>Description</th>
<th>Case 2</th>
<th>Case 1</th>
<th>Saving</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total</td>
<td>£3680.75</td>
<td>£4563.48</td>
<td>£742.73</td>
</tr>
</tbody>
</table>

This would give a saving of 16.27% on the above project.

Looking at the above, companies may prefer to cable as in case 1, as it gives more flexibility.
A fresh look at the provision of bandwidth to a health agency

In an existing installation a pair of twin RJ45 sockets exist. One for voice and the other one for data as a new user needs a phone and computer network point. Now instead of wiring the a new set of points, by using both the outlets for voice and data, the cost and time saving would almost be 100%. This would apply for both materials and labour but the greatest saving would be in time waiting for installers to run and terminate the cables.
10. Convergence of Telephony and Data Structures

Even though Cat 5 cable can be used for both voice and data concurrently this is hardly ever done. In some cases two outlets side by side are wired as Cat 3 for voice and Cat 5 for data. Where some integration has occurred a double Cat 5 sockets, one marked data, the other marked voice are provided, which makes for a more sightly layout. The non-integration is traditional as the Telecommunication Manager and the Data Processing Manager planned their networks separately each responding to the growth and needs of the end user (the same end user). This structure is shown in Figure 9-1.

Traditionally PABX systems were about processing voice calls and getting phones on desks. A fax machine got its own PSTN line and that was as close to data as the phone system went. On the other hand, the Data (computer) Department concentrated on connecting dumb terminals, or in later years computers, to their network. The only contact had with a telecommunications company was in dealing with leased lines. Despite the fact that Government bodies received instructions in September 1987 that cabling was to be done in future for voice and non-voice (i.e. data, text and image) and X acquisition which would switch non-voice communication (e.g. data). To this day one can find ‘Voice cabling’ being done by electrical contractors while Data network cablers do the ‘Data Cabling’. This is changing as can be seen from figure 9-2 where there are built-in channels of communication between the streams. Both figure 9-1 and 9-2 are from Taylor B, Managing a Corporate Communications Network, NCC publications Manchester.
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MANAGING A CORPORATE COMMUNICATIONS NETWORK

Figure I.1 Typical Compartmentalised Organisational Structure for Managing Medium to Large Scale Communications Networks

Figure 10-1 Split corporate structure and new organisation structure
Figure 10-2  New Organisational structure

10.1. Integration not only in structure but in technologies

With the digitisation of telecommunications not alone did the exchanges become digital but the PABXs did also. Having end equipment that was digital, opened the way to deliver digital connectivity to the PABX, this was done using a PCM (pulse code modulation) system (consisting of 32 time slots of 64Kb, 30 useable channels for calls transmission, 1 time slot for signalling and 1 time slot for synchronisation).
Now instead of 30 pairs of wires with a phone number on each there was one interface with 30 useable 64K time slots each able to carry a phone call. These digital systems were split into either incoming or outgoing channels. The usual set-up was 15 channels each way. The PCM system worked on 10 pound PCM cable or between exchanges where the trunk cable is 10 pound cable or greater, with repeaters every 2000 yards which meant just replacing the loading coils with repeaters. The first broadly used PCM system in Ireland was the Telectron PM30 system, which complied with G.700 series of C.C.I.T.T. recommendation for 30-channel PCM, which was the standard at that time. The repeaters were placed in spacing capable of catering for a maximum cable loss of 36dB at 1Mhz. For .9mm cable (i.e. 20lbs/mile or 19 AWG) cable the repeater spacing was 1.83 km with a maximum line voltage of +77v to -77v and a current of 49mA. The line code used was Alternate Mark Inversion (AMI)^ and High Density Bipolar 3 (HDB3)^. The above system was designed to work from Exchange to Exchange.

The pattern of bits " 1 0 0 0 0 1 1 0 " encodes to " + 0 0 0 0 - + " (the corresponding encoding using HDB3 is " + 0 0 0 + - + ").

---

^ AMI (Alternate Mark Inversion) coding was used extensively in first generation PCM networks, but suffers the drawback that a long run of 0's produces no transitions in the data stream. The HDB3 encoding scheme is one of many which have been developed to provide regular transitions irrespective of the pattern of data being carried.

^ HDB3 (High Density Bipolar Order 3) code is a bipolar signalling technique (i.e. relies on the transmission of both positive and negative pulses). It is based on AMI, but extends this by inserting violation codes whenever there is a run of 4 or more 0's. To prevent a dc voltage being introduced by excessive runs of zeros. This refinement is to encode any pattern of more than four bits as B00V. The value of B is assigned as + or - alternately throughout the bit stream.
In 1987 even though Telecom Eireann (the Irish PTT) had installed PCM between exchanges it did not have a commercial service to customers. To deliver PCM to Customers or between Customer premises, the choices were to install PCM Cable or use the existing cable in the ground. Using the knowledge of the cable make up, and by putting transmit and receive circuit in separate bundles, allowed PCM systems to be installed at lower cost.

If the PCM system was installed between premises, Companies now had the choice of using this 2Mb circuit to carry voice and data. Again depending on who ordered the circuit the mixing would be done by a Multiplexer using TDM if the Data staff were
A fresh look at the provision of bandwidth to a health agency

the owners while if the Circuit was terminated on the PABX then the data staff could use the discrete 64Kb channels for dial up data. It is important to remember that data circuits of 9.6Kb were the norm at this time.

In the 1990's two developments happened,

- First the development of DSL technologies changed the way that bandwidth could be delivered. It allowed the cable between buildings to provide bandwidth sufficient to support most applications. Provided the correct equipment is used. This can only be done if the number of cables, their size, condition, other users, the number spare pairs available, the future use of the link, will allow.

- Second the development of ISDN or Euro ISDN as it was standardised as in Europe. There are two versions the ISDN 2 or Basic Rate providing two useable channels and the ISDN 30 or Primary Rate providing thirty useable channels. The D channel provides the signalling between Exchange and the customer equipment whether that is a data router or PABX.

10.2. Digital Subscriber Line

The name Digital Subscriber Line (DSL)\(^8\) refers to the modem type boxes that are placed at either end of one or more pairs of wires. It has been described by the ADSL

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\(^8\) The ITU-T xDSL standards have been "determined" which means they are stable & will then undergo a 9 month review before being "approved". For all practical purposes, determination is approval - changes are mainly editorial & clean-up after that. The g.hdsl standard (G.991.1) was determined in February and was approved this October. The numbers of the set are:

G.991.1 (ex-G.hdsl) High Speed Digital Subscriber Line (HDSL)

G.992.1 (ex-G.dmt) Asymmetrical Digital Subscriber Line (ADSL) transceivers (this is the ITU-T's version of full-rate ADSL)

G.992.2 (ex-G.lite) Splitterless Asymmetrical Digital Subscriber Line (ADSL) transceivers
A fresh look at the provision of bandwidth to a health agency forum as ‘A technology that exploits unused frequencies on copper telephone lines to transmit traffic, typically at multi-megabit speeds. DSL can allow voice and high-speed data to be sent simultaneously over the same line. Because the service is ‘always on’, end users don’t need to dial in or wait for call set-up’ (http://www.adslforum.org/).

Where confusion can arise is the number of letters that prefix the letters DSL (I, A, V, H, B, S, VA) as there are different names for the same product not to mention the difference between the USA and Europe.

DSL comes in two styles:

G.994.1 (ex-G.hs) Handshake procedures for Digital Subscriber Line (DSL) Recommendations
G.995.1 (ex-G.ref) Overview of Digital Subscriber Line (DSL) Recommendations (reference diagrams)
G.996.1 (ex-G.test) Test procedures for Digital Subscriber Line (DSL) transceivers (gives noise models, loop models, POTS models, and some test procedures. Performance requirements are in the respective specs (e.g., G.992.2), and in G.test)
G.997.1 (ex-G.plom) Physical layer management for Digital Subscriber Line (DSL) transceivers - this gives MIBs and management interfaces for the various xDSL interfaces
G.992.1 (ADSL) has several annexes, defining operating modes. The principle ones are:
- Annex A - Specific requirements for an ADSL system operating in the frequency band above POTS
- Annex B - Specific requirements for an ADSL system operating in the frequency band above ISDN (European)
- Annex C - Specific requirements for an ADSL system operating in the same cable as TCM-ISDN (Japanese).
G.992.2 (G.lite) also has annexes:
- Annex A - Non overlapped spectrum operation (normal mode - FDM)
- Annex B - Overlapped spectrum operation (this defines "echo-cancelled mode")
- Annex C - Operational in the same cable as TCM-ISDN (Japanese)
It is expected that Annex A will be specified by ANSI for US operation.
There is no "G.lite over ISDN" similar to Annex B of G.992.1
Key features of G.992.2 (lite) are:
- Power management (allows for an optional low-power, low-bit rate operation, as well as defines the transition into an IDLE mode (which is equivalent to the transceiver being off.)
- Fast Retrain capability (Allows for 5 to 2.2 second startups using (vendor-discretionary) line probing selection of a known stored line profile. This was originally only for recovery from phone off-hook events but now includes transition out of the various power management states.
- There are a number of technical simplifications in lite. It allows bit rates up to 1.5 Mbps downstream and 512 kbps upstream. It has no standard option for trellis coding and bit swap is optional. It uses tones up to 128 in the downstream direction (halving the bandwidth of full rate). Generally, changes relative to T1.413 issue 2 have been minimized. There were several proposals for different operating modes and modified framing, but these were not adopted.

One key difference of the G xDSL recommendations from T1.413 is the new G.994.1 handshake. This allows for multi-mode modems, so it should be possible to support both G.lite and G.dmt. The work goes on. The group also agreed to start work on VDSL and HDSL2/SDSL (SDSL is Europe’s name for HDSL2, which is focused more like a continuum of rate adaption steps between ISDN and HDSL). They are called G.shdsl and G.wdsl. Also beginning are the 2nd generations of G.lite and G.dmt which are scheduled to be done in April 2000. Finally, review of the current documents for errors is beginning and will be the major subject of the next meeting which is in January.
G.993 is reserved for VDSL, and G.991.2 is expected to be used for HDSL2.
PairGain Technologies
December 4, 1998
Symmetric DSL supports the same data rates for upstream and downstream traffic from the central office to the customer (the desk top in our case). Some variations include: IDSL, SDSL, HDSL, HDSL-2 and SHDSL and IDSL

- **IDSL**: (integrated services digital network DSL). This is a form of DSL that supports symmetric data rates of up to 144 Kbps using existing phone lines. IDSL differs from its relative ISDN (integrated services digital network) in that it is an “always-on” service, but capable of using the same terminal adapter, or modem, used for ISDN.

- **SDSL**: (symmetric DSL) SDSL is a vendor-proprietary version of symmetric DSL that may include bit-rates to-and-from the customer ranging from 128 kbps to 2.32 Mbps. The equal speeds make SDSL useful for LAN (local area network) access, and video-conferencing. SDSL is an umbrella term for a number of supplier-specific implementations over a single copper pair providing variable rates of symmetric service. SDSL employs the widely-used 2B1Q modulation, but the industry is expected to quickly move towards the higher performing and standardized G.shdsl technology developed by the ITU with support from T1E1.4 (USA) and ETSI (European Telecommunications Standards Institute).

- **SHDSL** is state-of-the-art, industry standard symmetric DSL. SHDSL equipment conforms to the ITU Recommendation G.991.2, also known as G.shdsl, expected to be approved by the ITU-T in 2001. SHDSL achieves 20% better loop-reach than older versions of symmetric DSL, it causes much less crosstalk into other transmission systems in the same cable, and multi-vendor interoperability is
facilitated by the standardization of this technology. SHDSL systems may operate at many bit-rates, from 192 kbps to 2.3 Mbps, thereby maximizing the bit-rate for each customer. G.shdsl specifies operation via one pair of wires, or for operation on longer loops two pairs of wire may be used. For example, with two pairs of wire, 1.2 Mbps can be sent over 2Km of 26 AWG wire.

- **HDSL**: (high data rate DSL) This variety created in the late 1980s delivers symmetric service at speeds up to 2.0 Mbps in both directions. Available at 1.5 or 2.0 Mbps. Used as an economical replacement for PCM T1 or E1, it uses one, two or three twisted copper pairs.

- **HDSL-2**: (2nd generation HDSL) This variant delivers 1.5 Mbps service each way, supporting voice, data, and video using either ATM (asynchronous transfer mode), private-line service or frame relay over a single copper pair. HSDL2 differs from HDSL in that HDSL2 uses one pair of wires to convey 1.5 Mbps whereas ANSI HDSL uses two wire pairs.

### 10.2.1. Line codes

In using DSL, or more specific ISDN there is differences between USA and Europe, the line code is the same but the amount of information is different. The modulation code used is 2B1Q the transmitted signal is between +13 and +14dBmW over a frequency band from 0 Hz and 80 Hz. The waveform is +3, +1, -1, -3 each of these voltages represents two bits on the binary side. The 2B refers to 2 Binary Bits 1Q refers to one of four levels on the line side.
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**Figure 10-4  2B1Q code make up**

The Bit rate is made up of 2 @ 64Kb channels (B), 1 @ 16Kb Channel (D), Overheads. This overhead varies in Europe is 48Kb giving a total of 192Kbs or 96Kbd, in USA the overhead is 16Kb giving 160Kbs or 80Kbd.

Equipment that is designed for ISDN is designed to work in a switched environment where pure DSL is point to point.

10.3. Asymmetrical DSL

Asymmetrical DSL (ADSL) supports a slower data rates for upstream than downstream traffic from the central office to the customer (suited to web style applications or the down loading of X-rays for reporting). Some variations include: ADSL, G-lite ADSL, RADSL, VDSL

- **ADSL:** (Full Rate asymmetrical DSL) ADSL offers differing upload and download speeds and is usually configured to deliver up to 6Mb from the network and 6Kb from the customer ADSL enables voice and high-speed data to be sent simultaneously over the existing telephone line. Good for general Internet access
A fresh look at the provision of bandwidth to a health agency

and for applications where downstream speed is most important, such as video-on-demand. ITU-T Recommendation. G.992.1 and ANSI Standard T1.413-1998 specify full rate ADSL.

- **G.lite ADSL (or simply G.lite):** The G.lite standard was ratified in 1999. It is a standard ADSL service for the delivery of speeds of up to 1.5 Mb downstream and up to 500 Kb upstream. G.lite is an International Telecommunications Union (ITU) standard globally standardized interoperable ADSL system per ITU G.992.2.

- **RADSL** (rate adaptive DSL) A non-standard version of ADSL. Note that standard ADSL also permits the ADSL modem to adapt speeds of data transfer.

- **VDSL** (very high bit rate DSL) Up to 26 Mb/s, on very short lines. In most cases, VDSL lines will be served from neighborhood cabinets that link to a Central Office via optical fiber. It is particularly useful for ‘campus’ environments – universities and business parks, for example. VDSL is currently being introduced in market trials to deliver video services over existing phone lines.

- Just as with PSTN systems having all these DSL technologies available and with mega bits travelling on cables they induce crosstalk, their power densities as shown in figure 9-4.
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Figure 10-5  Frequency versus Power spectral density for DSL's

It can be seen that for HDSL the power is concentrated below 700KHz but for a T1 circuit the power is higher for all frequencies over 200KHz allowing a greater distance between regenerators or terminal equipment. PairGain Technologies have carried out tests on the affect of a combination of 39 HDSL2 and 10 T1 signals in the same binder.

Figure 10-6  The power Spectral Density of the circuits under test
They then continued to show how their equipment deals with the crosstalk generated into any one system. The signal to noise ratio delivered by their equipment is also shown.

Figure 10-7 SNR performance of PairGain’s equipment
11. Physical integration

As mentioned the voice and data administration has been kept separate and this has led to a different approach in the deployment of the infrastructure. The textbook delivery of telephony is to terminate the PABX extensions on the Main Distribution Frame (MDF). In this case a number of large cables leave the MDF and head to Intermediate Distribution Frames (IDF) situated in central locations in wings of large buildings or in the centre of buildings on the campus. From this point smaller cables are run to floors, from here the phones are connected via either two or four pair cable.

![Diagram of telephony infrastructure](image)

**Figure 11-1  Telephony infrastructure schematic**

The provision of a telephone starts by jumpering the extension position to a Main Cable pair at the MDF going to the IDF and cross-connecting to a cable going to the...
A fresh look at the provision of bandwidth to a health agency area where the phone is required. The final part is picking up a free pair in a cable from the last IDF to the room, or running a new cable. As time goes by the location of IDF's can become vague and records can become misleading.

Because of the distance limitations of the data network, (i.e. max of 90m from the wiring closet to the outlet) and the structured nature of the cabling, each outlet is marked at both the room outlet and in the closet. Also the fact that each closet has active equipment housed within it makes it more a concentrated point of activity.

In the provision of data connectivity, the room’s outlet number is taken, and the active equipment is connected to the wiring closet side of the cable. Only when a new wiring closet is required has the core or backbone of the network to be added to, usually by connecting fiber to the wiring closets at either side so as to give redundancy.

Figure 11-2 Data infrastructure schematic
By connecting the MDF directly to the wiring closet on patch panels then the provision of telephony becomes the same as the provision of data, except that instead of connecting to the active equipment it is now connected to the telephony patch panel. Then the main cable pair associated with the patch panel outlet can be jumpered to the PABX extension on the MDF.

Figure 11-3  Integrated wiring schematic
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The above examples work well in a building where both a voice and a data core are present but in locations where the telephone cable is already in place between buildings there are two main applications that may be required.

- The delivery of data from the core to remote buildings. Some of these sites have only one user and others have up to 50 users.

- The deliveries of voice to remote buildings. Some of these sites have single users while others require a full 2Mb connection between PABX's.

The Southern Health Board has a number of solutions for the delivery of data and voice, both separately and integrated.

In one campus the end users were infrequent users of data but required frequent voice connectivity. The first approach tested was the provision of Basic rate access from a SILC\(^9\) card in the Nortel PABX on the campus. However this was found not to be stable as the installed cable pairs were of poor quality. A second approach was taken by replacing the SILC with a UILC\(^10\), which delivers U-bus interfaces and by changing the Customer Premises Equipment (CPE) to CPE with U interfaces. Thus suppling the end users with an easy to install and flexible solution. The distance that a U bus can work is about 3 times that for a S bus. Also the fact that a S bus has two pairs both need to be of the same quality.
The CPE finalised upon was an ISDN router that has, as mentioned earlier a U-bus interface, two PSTN interfaces and an Ethernet interface, the unit used was a Cabletron SSR 140. The installation is a simple matter of ceasing the existing phone extension, connecting the MCP to the SILC then connecting the SSR instead of the phone. The phone can be reconnected to the SSR and when the ISDN extension is enabled, the phone is back in service with the user seeing only a possible change in number. An end user can be upgraded by one so-called ‘Truck role’ from the central location. The user’s computer can be connected to the SSR, the only requirement here is an ISDN access device for the SSR to dial into. This is the only overhead but the grade of service \(^{11}\) for the users has to be agreed. As all devices are connected to the one PABX there is no cost for each call.

As the number of end users requiring data access in the area became larger, the Board used two approaches. One the use of HDSL modems to provide a 2Mb stream, if these

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\(^9\) S - Interface Line Card the in combination with a MISP (Miscellaneous Signaling Processor) delivers 8 S-bus connections per SILC.

\(^{10}\) Similar to SILC but delivers 8 U-bus interfaces

\(^{11}\) Grade of Service is the ratio of users accessing ports to the number of available ports.
modems are fitted with X21 interfaces they can be connected to routers at either building. The CPE used in this solution was the Nokia HDSL modems, which can use either use one, two or four pairs.

Figure 11-5  Nokia HDSL modem

The modems provide the installer with two sources of information, one the receive dB level, and the other the quality of this received signal. In setting up one set of modems, the receive dB level was within the limits for a good circuit but the circuit was unstable. Even the use of four pairs (approx 1Mbit on each of the two pairs) did not bring the quality to an acceptable level. By going to each cable on the route and placing the two transmit pairs in the same bundle and the receive in another and by using Cat 5 cable to jumper at each IDF the quality was greatly improved and it was stable. It is important to note that the receive dB level did not improve from the initial level when using one pair. To see if having the transmit pair and receive pair in different bundles was the reason the circuit worked, the transmit and receive of each
A fresh look at the provision of bandwidth to a health agency

1Mb circuit were placed in each bundle using the same pairs as the working set-up and once again the circuit became unstable.

If both ends of the circuit terminate in sites with data switches, Cabletron have a product, which is an insert that fits into the HSIM of the Smartswitch 2200 series, this insert needs two pairs to give a connection of 1.5Mb. Thus as here it only required a pair of HSIM’s and DSL inserts, it was more cost effective than the Nokia / Cisco solution as long as cable pairs were available.

However this product was superseded by the FlowPoint 2200\textsuperscript{12} from Cabletron, which is a SDSL router, that auto senses between 2.5Mb to 750Kb depending on the quality of the cable pair. It has four Ethernet ports, so for a group of users up to and including four, they can have a shared hub that can be either routed or bridged back to the FlowPoint 2200 in the central site. This in turn is connected to a switched port giving 10Mb switched to the link. This solution is cost effective if less than six boxes are needed in any site. If more six are needed as the FlowPoint 2200 work back to back, with one side the centre (CO) and the other the remote (CPE), the central site can also get quite untidy and space has to be found for each router.

\textsuperscript{12} FlowPoint was owned by Cabletron and late 2000 sold to Efficient early 2001 sold to Siemens
FlowPoint 2200

Figure 11-6  Cabletron FlowPoint SDSL Router

The different options have been summed up by FlowPoint in a schematic diagram shown in figure 10-7.

**BUSINESS DSL, CABLE AND WIRELESS INTEROPERABILITY**

![Schematic of DSL interconnection]

Figure 11-7  Schematic of DSL interconnection
A fresh look at the provision of bandwidth to a health agency

The solution to this crowding is to install a DSLAM\textsuperscript{13} in the central location this can connect to either 20 or 40 remote sites depending on the DSLAM used. The CPE is the FlowPoint 2200 with a different software code loaded to the back to back operation above.

Figure 11-8 A Nortel schematic including DSLAM and Remote routers

The uplink from a DSLAM is usually, either four 2Mbps interfaces that can be configured in an IMA\textsuperscript{14} group, or an OC3\textsuperscript{15} link. If a data switch has the ability to take an OC3 link then this is the most cost effective way to deliver Ethernet IP from the data switch to the remote site via the DSLAM.

\textsuperscript{13} DSL Access Multiplexer
\textsuperscript{14} An ATM Simulation on a 2Mbps or across two to four 2Mbps
\textsuperscript{15} ATM link at155Mbps
11.1. DSL for Voice delivery

The connection of two PABXs is provided in a number of ways, the original using Nokia modems with G703 75Ω, or 120Ω connections. The most important setting is the clocking and this should be set so that one side at the main site (the site with a PRI from the telecommunications operator) is set to external clock while the remote site is set to clock from the line. Otherwise they will not be synchronized and will give slips and loss of frame synchronization. This synchronization keeps the receive clock at the same rate as the clock of the transmit system these need not be at exactly 2.048Mb but within limits of ± 50 bits per second.

As well as the Nokia solution a HDSL modem from Orkit is also used between PABXs but to get DSL information a terminal connection is needed to the modem. The Orkit requires two pairs to provide 2Mb. It is similar to the Nokia in that it is fitted with both 75Ω and 120Ω interfaces, it sometimes is convenient to have 120Ω at one end and 75Ω at the other.

Figure 11-9  Orckit HDSL Modem
A fresh look at the provision of bandwidth to a health agency

The other option in linking PABX's is to use Voice Over IP (VOIP) here once again there are two options from Nortel

- The Remote office 9150, which has been discussed earlier in the development of the FECV2.
- The ITG2 VOIP gateway, a card that sets in the PABX and can act as a digital trunk card, with the data network seen as a cloud through which any extension can talk to another across the IP network. This card can also work as a digital extension card from which the i2004 Ethernet phones work.

The VOIP compression used by Nortel is G728A, which uses 8Kb for the voice encoding, and overheads of approximately 5Kb. There are two ways of protecting these packets from distortion

- Marking the packets as voice packets and having the active equipment prioritise the traffic
- Having excess bandwidth for the load on any link, or having only voice on a link even though that link is carrying IP traffic.
12. Pricing Telecommunications

12.1. Introduction

Pricing of Telecom services has always been a black art with the telecom operators informing companies that this or that product is the solution and that it is cheaper than either your present solution or their competitor’s offering. When they talk of solution they are talking of the product that they sell whether that be voice traffic or data connectivity. They are only, as the name suggests, concerned with connectivity. In the days of M1020 (a 4 wire circuit guaranteed to connect modems at 9.6Kbits) the carrier had control as far as the AFLU (a 4 wire unit that allowed the circuit to be looped in different direction). With digital Leased Lines the presentation is either X21 n * 64Kbps and G703 at 2Mbps in this case the carrier controlled the modem.

12.2. Database solution

To help with the calculation of Leased Lines from M1020 to 2Mbits I devised a database package to calculate the costs of the circuits and allow myself to check different combinations. Some of these would be:

- Do I bring all circuits to a central location in a star formation
- Go from A to B and then to the central location

By being able to model the circuit costs and output the results to excel gives me a tool that makes the costing of network design easier.
A fresh look at the provision of bandwidth to a health agency

Table 12-1 Leased Line costing
(See appendix E).

12.3. Spreadsheet solution

In some cases the usage from a location may seem small and the number of days for example a clinic is open per week may be only one or two, so having got the Leased Line cost the next procedure is to decide can the service be done on a PSTN / ISDN dialup or not. To help me with this I developed an excel spreadsheet to calculate the cost of calls over a year this then could be added to the capital cost and rental to give the true cost of connecting a site to the corporate network. After doing these calculations for a number of sites rules of thumb become apparent and this makes network design and costing easier and quicker.

The next section deals with the analysis of real circuits.
12.4. The Cost of a System

12.4.1. To dial or not to dial

When the bandwidth requirements of a circuit have been decided the main choices are as follows; Dial up, or Leased Line, (whether the Leased Lines are terminated on X21 or E1). With dial up the cost is proportional to the use. To calculate this the following information must be gathered:

- Number of users
- Hours per day per user (peak and or non peak)
- Days per week
- Weeks per year
- Are the uses concurrent (if two users use the system for 2 hours a day at the same time the length of time is reduced but the bandwidth required may be larger)
- Call charge (per sec pulse)
- The number of calls if more than one is needed (n*64k)

For an example of the costing I took an area of north Cork with Mallow in the centre and 6 by 64K circuits from other towns and a 128K circuit back to Aras Slainte. All sites are within the local call area. For this example one link will be compared between Dial up PSTN / ISDN and Leased Line, and a second calculation based on a single Leased Lines versus E1 in Mallow.

The Leased Line charges used are the ones from Millstreet to Mallow as these are the highest of the group tested. If Leased Line is more cost effective, then for all sites it
A fresh look at the provision of bandwidth to a health agency should be similar. From the database program the Leased Line cost for a 64K circuit is £2,915.6.

<table>
<thead>
<tr>
<th>PEAK</th>
<th>£ per pulse</th>
<th>hrs/day</th>
<th>min</th>
<th>pulses</th>
<th>£</th>
<th>sec</th>
<th>£ per sec</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>0.095</td>
<td>5.5</td>
<td>330</td>
<td>110</td>
<td>£10.45</td>
<td>19800</td>
<td>0.055</td>
<td>10.89</td>
</tr>
<tr>
<td>Week/days</td>
<td>5</td>
<td>27.5</td>
<td>Number of days used in a week</td>
<td>52.25</td>
<td>54.45</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Year</td>
<td>52</td>
<td></td>
<td>Number of weeks in a year</td>
<td>27/10</td>
<td>2831.4</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pulse length</td>
<td></td>
<td></td>
<td>Pulse length in Minutes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OFF PEAK</th>
<th>£ per pulse</th>
<th>hrs/day</th>
<th>min</th>
<th>pulses</th>
<th>£</th>
<th>sec</th>
<th>£ per sec</th>
<th>£</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>0.095</td>
<td>0.5</td>
<td>30</td>
<td>2</td>
<td>£0.19</td>
<td>1800</td>
<td>0.0138333</td>
<td>0.249</td>
</tr>
<tr>
<td>Week/days</td>
<td>6</td>
<td>3</td>
<td></td>
<td></td>
<td>1.14</td>
<td></td>
<td></td>
<td>1.494</td>
</tr>
<tr>
<td>Year</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
<td>59.25</td>
<td></td>
<td></td>
<td>77.688</td>
</tr>
<tr>
<td>Pulse length</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| PSTN line rental | £131.04 | £131.04 |
| Call Costs | £2,776.28 | £2,909.09 |

| Leased | £2,915.6 |
| ISDN | £348.00 |
| Costs of using a phone line and calls | £3,040.13 |

| Leased line rental | £2,915.6 |
| ISDN Rental | £348.00 |
| Costs per pulse the leased line rental equates to | £0.10 |

Table 12-2  Leased Line versus Dialup

The concurrent use at peak rate is 5.5 hours for 5 days and an off peak time of 0.5 hours for 6 days a week. A 52 week, year will be used, as the hospital in Millstreet could be an end user. The call rate is local 3 minutes per pulse peak and 15 min per pulse off peak. And the newer per second billing from Eircom.
The Leased Line cost is fixed at the figure mentioned above but the PSTN / ISDN are made up of two costs, the fixed line rental and the calling costs, which will be the same for both if using one ISDN channel. From the table the Leased Line costs £2,915.6, the PSTN costs £3,040.13, and the ISDN costs £3,257.09.

Missing from these figures are the following; connection fees and terminating equipment for the Leased Lines and PSTN / ISDN connection fees and terminating equipment. The connection fees are set but the equipment costs can vary depending on the type of user being catered for. There are in theory 3 types of user:

- A computer and modem connected to the PSTN and dialling a modem connected to a router in the main location.
- A computer connected to an ISDN router dialling another router in the main location.
- A computer connected to a Leased Line router connected back to the main site.

(An assumption of 3 end users is being made).
A fresh look at the provision of bandwidth to a health agency

Putting figures on these charges the following table is created.

<table>
<thead>
<tr>
<th>Connection per end</th>
<th>PSTN</th>
<th>ISDN</th>
</tr>
</thead>
<tbody>
<tr>
<td>a end</td>
<td>82</td>
<td>348</td>
</tr>
<tr>
<td>b end</td>
<td>82</td>
<td>348</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>164</strong></td>
<td><strong>696</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equipment per end</th>
<th>PC/Modem</th>
<th>PC/Cisco</th>
</tr>
</thead>
<tbody>
<tr>
<td>a end</td>
<td>1240</td>
<td>2028</td>
</tr>
<tr>
<td>b end</td>
<td>2400</td>
<td>888</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3640</strong></td>
<td><strong>2916</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Dial up Total</th>
<th>3804</th>
<th>3612</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Per Next user</td>
<td>1540</td>
<td>3080</td>
</tr>
<tr>
<td>2 Per Next user</td>
<td>2028</td>
<td>4056</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leased Line</th>
<th>64K</th>
<th>128K</th>
</tr>
</thead>
<tbody>
<tr>
<td>a end</td>
<td>750</td>
<td>750</td>
</tr>
<tr>
<td>b end</td>
<td>750</td>
<td>750</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1500</strong></td>
<td><strong>1500</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equipment per end</th>
<th>PC</th>
<th>PC</th>
</tr>
</thead>
<tbody>
<tr>
<td>a end</td>
<td>2958</td>
<td>2958</td>
</tr>
<tr>
<td>b end</td>
<td>1818</td>
<td>1818</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>4776</strong></td>
<td><strong>4776</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Leased Line Total</th>
<th>6276</th>
<th>6276</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 Per Next user</td>
<td>1140</td>
<td>2280</td>
</tr>
<tr>
<td></td>
<td>8556</td>
<td>8556</td>
</tr>
</tbody>
</table>

Table 12-3  Dialup Analysis

Table 12-4  Leased Line Analysis

The Leased Line capital costs are greater but as the numbers grow the incremental costs increase at a slower rate to those of the dial up solution.
A fresh look at the provision of bandwidth to a health agency

Having defined the capital and current charges by analysing the type of application in relation to the bandwidth used and seeing the costs over 2 years, we now have the overall picture.

**Analysis of the combinations**

<table>
<thead>
<tr>
<th>Modem / PC</th>
<th>Capital</th>
<th>Rental / Calls</th>
<th>One</th>
<th>Two</th>
<th>Three</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leased line 64K</td>
<td>£8,556</td>
<td>£2,916</td>
<td>£11,472</td>
<td>£14,387</td>
<td>£17,303</td>
</tr>
<tr>
<td>128K</td>
<td>£8,556</td>
<td>£3,477</td>
<td>£12,033</td>
<td>£15,509</td>
<td>£18,986</td>
</tr>
<tr>
<td>Dialup</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ISDN 64</td>
<td>£7,668</td>
<td>£3,257</td>
<td>£10,925</td>
<td>£14,182</td>
<td>£17,439</td>
</tr>
<tr>
<td>PSTN</td>
<td>£6,884</td>
<td>£3,040</td>
<td>£9,924</td>
<td>£12,964</td>
<td>£16,004</td>
</tr>
<tr>
<td>ISDN 128</td>
<td>£7,668</td>
<td>£6,514</td>
<td>£14,182</td>
<td>£20,696</td>
<td>£27,211</td>
</tr>
</tbody>
</table>

Table 12-5  Combination Analysis

Further analysis of the figures shows the difference between the choices to be small except for dial up 128K ISDN. Having a 64Kb line and computers would be seen as having the most development potential.

12.4.2. To E1 or not E1

The next part of the analysis is to see if it would be cost effective to install an E1 circuit in Mallow.

<table>
<thead>
<tr>
<th>EXCH1</th>
<th>EXCH2</th>
<th>type</th>
<th>E1 cost</th>
<th>E1 connection</th>
<th>LL cost</th>
<th>LL connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>MALLOW</td>
<td>KANTURK</td>
<td>64K</td>
<td>£1,644.00</td>
<td>£750.00</td>
<td>£2,395.00</td>
<td>£1,500.00</td>
</tr>
<tr>
<td>MALLOW</td>
<td>RATHLUIRC</td>
<td>64K</td>
<td>£1,926.00</td>
<td>£750.00</td>
<td>£2,677.00</td>
<td>£1,500.00</td>
</tr>
<tr>
<td>MALLOW</td>
<td>FERMOY</td>
<td>64K</td>
<td>£1,973.00</td>
<td>£750.00</td>
<td>£2,724.00</td>
<td>£1,500.00</td>
</tr>
<tr>
<td>MALLOW</td>
<td>MITCHELSTOWN</td>
<td>64K</td>
<td>£2,161.00</td>
<td>£750.00</td>
<td>£2,912.00</td>
<td>£1,500.00</td>
</tr>
<tr>
<td>MALLOW</td>
<td>MILLSTREET</td>
<td>64K</td>
<td>£2,164.60</td>
<td>£750.00</td>
<td>£2,915.60</td>
<td>£1,500.00</td>
</tr>
<tr>
<td>MALLOW</td>
<td>DUNNEYS CROSS</td>
<td>128K</td>
<td>£2,575.00</td>
<td>£750.00</td>
<td>£3,470.00</td>
<td>£1,500.00</td>
</tr>
<tr>
<td>MALLOW</td>
<td>NEWMARKET</td>
<td>64K</td>
<td>£1,973.00</td>
<td>£750.00</td>
<td>£2,724.00</td>
<td>£1,500.00</td>
</tr>
<tr>
<td>MALLOW</td>
<td>MALLOW</td>
<td>E1</td>
<td>£5,000.00</td>
<td>£5,000.00</td>
<td>£0.00</td>
<td>£0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Cost in YR 1</th>
<th>Cost in YR 2</th>
<th>Cost in YR 3</th>
<th>3 Year Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>£19,416.60</td>
<td>£19,416.60</td>
<td>£19,416.60</td>
<td>£68,499.80</td>
</tr>
<tr>
<td></td>
<td>£10,250.00</td>
<td>£10,250.00</td>
<td>£10,250.00</td>
<td>£69,952.80</td>
</tr>
</tbody>
</table>

Table 12-6  Circuit Comparison
A fresh look at the provision of bandwidth to a health agency

From the above table it can be seen that the E1 has paid for itself and any more circuits will increase the saving even more. The cost of equipment must once again be taken into account and the following table shows this.

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Price</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cisco 1603 R Ethernet/ISDN-BRI Modular Router</td>
<td>7</td>
<td>1,010.00</td>
<td>7070</td>
</tr>
<tr>
<td>Power Cord UK</td>
<td>7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1-Port Serial WAN Interface Card</td>
<td>7</td>
<td>270</td>
<td>1890</td>
</tr>
<tr>
<td>X.21 Cable, DTE, Male, 10 Feet</td>
<td>7</td>
<td>70</td>
<td>490</td>
</tr>
</tbody>
</table>

9,450.00

<table>
<thead>
<tr>
<th>Description</th>
<th>Quantity</th>
<th>Price</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cisco 1603 R Ethernet/ISDN-BRI Modular Router</td>
<td>4</td>
<td>1,010.00</td>
<td>4040</td>
</tr>
<tr>
<td>Power Cord UK</td>
<td>4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1-Port Serial WAN Interface Card</td>
<td>7</td>
<td>270</td>
<td>1890</td>
</tr>
<tr>
<td>X.21 Cable, DTE, Male, 10 Feet</td>
<td>7</td>
<td>70</td>
<td>490</td>
</tr>
</tbody>
</table>

6,420.00

**Table 12-7 Remote Leased Line CPE**

**Table 12-8 Remote and E1 CPE**
The difference of £825.00 in favour of the stand-alone circuits should be put against the difference in circuit costs where in year one the E1 has the advantage by £651.00 and by £401.00 in both year two and three. The ease of use and control of having only one router and one interface to programme makes the E1 the system of choice in this case.
13. Wireless LAN

Having used Spread Spectrum technology in the FECV for the implementation of radio LAN or wireless LAN (WLAN) as it is now known, further investigation of the system's capabilities was called for. As the name suggests WLAN is the delivery of LAN connectivity over air. To understand WLAN limitations, uses and how it works we need to examine the comparison with wired LAN networks and interconnection with wired LANs. In order to do this different configurations of wireless networks, the different protocols used to deliver the technology, and WLANs ability in the future to deliver a true convergent wireless solution must be examined.

In investigating the technology the following areas were examined:

- Spread Spectrum technology
- Standards
- Futures
- Products in production and those used by the Southern Health Board
- Convergence

13.1. Spread Spectrum theory

Spread spectrum as the name suggests is the dispersal of the transmitted signal across the available bandwidth.

The frequency ranges allocated for spread spectrum transmission vary depending on location. For Europe it is in the 2.4 GHz band at a maximum power of 1mw. Complying with IEEE 802.11 specifications.
There are two ways of implementing spread spectrum these are as follows:

- Direct Sequence Spread Spectrum (DSSS)
- Frequency Hopped Spread Spectrum (FHSS)

13.1.1. Direct Sequence Spread Spectrum

Direct Sequence Spread Spectrum technology combines the data to be transmitted with a higher rate bit sequence, known as a chip sequence. This higher rate bit sequence is modulated with the user data, this determines a figure of merit for DSSS systems known as processing gain, or spreading ratio. A ratio of ten is common. Since the spreading process is applied to each data bit, this method is known as direct sequence. Because the total transmitted power is spread across a wide frequency band as a result of this spreading process, power spectral density is much lower than with narrowband transmitters. One of the effects of a lower spectral density is that one cannot detect signals transmitted using this process. Thus narrowband radios will not interfere with a WLAN unless the WLAN receiver becomes overloaded. The fact that only one of the ten copies of the users data stream need be received and reassembled correctly, makes DSSS very robust.

13.1.2. Frequency Hopped Spread Spectrum

The frequency hopped technology spreads transmitted energy in the time domain. One or more of the raw data bits are transmitted on a single narrowband frequency. The transmitter then "hops" to another frequency, where another few bits are transmitted during the dwell time of 400ms. The system hops in a pseudo random, but known, sequence, and pause for a very short time to re-synchronise with the other radio before it can resume any data transmission.
The group of frequencies among which the transmitter jumps is known as hop sequences.

13.2. Comparisons of both systems

<table>
<thead>
<tr>
<th>Direct Sequence</th>
<th>Frequency Hopping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Latency time</td>
<td>Long Latency time</td>
</tr>
<tr>
<td>Processing Gain (Better S/N)</td>
<td>No Processing Gain</td>
</tr>
<tr>
<td>Fast Lock-in as radio synchronise</td>
<td>Slow Lock-in as radio Search the channel</td>
</tr>
<tr>
<td>No Dwell time</td>
<td>400 ms Dwell time</td>
</tr>
<tr>
<td>No re-sync necessary</td>
<td>Re-sync after each hop</td>
</tr>
<tr>
<td>Short Indoor Range</td>
<td>Short Indoor Range</td>
</tr>
<tr>
<td>Long Outdoor Range</td>
<td>Shorter Outdoor Range</td>
</tr>
<tr>
<td>Greater Data throughput</td>
<td>Lower Data throughput</td>
</tr>
</tbody>
</table>

Table 13-1 DDS vs FHSS

13.3. Spread Spectrum Design

A typical configuration of a generic LAN consists of an active devices (e.g. a Hub or a Switch) in the centre of the network, with servers connected at say 100Mbs and clients at say 10Mbs. If a remote site or location is required to be networked, the choices are a
Leased Line from a carrier with routers at either end or if there is copper in the ground
DSL routers can be deployed. These WAN links would be configured at 2Mbs or less,
for Leased Line, or at speeds of up to 2.5Mbs for DSL.

When using WLAN technology the building blocks are as follows:

- An Access Point (AP) is a functional Hub, which connects to the wired LAN
  via an Unshielded Twisted Pair connection. The wireless radio adapter is
  usually a PC Card, which inserts into the Access Point.

- A Mobile Device (MD) which can be connected to the wireless network by
  PCMCIA cards that plug into laptops or handheld devices, while desktop
  computers can be fitted with PCMCIA card adapters as a plug into a slot on the
  motherboard.

- A Cell is the coverage area for an AP this will vary with whatever material is
  within the coverage area. Some materials absorb the signal more than others;
  other active devices can also cause interferences.

- Roaming is the ability to move from one AP’s coverage to another without
  loosing the data session. Having overlapping cells can help this and can also
  provide load balancing.

- Wireless network device provides connectivity to devices that don’t have the
  ability to run client software such as printers and terminals.

- A Remote Power Adapter (RPA) (in our case from Cabletron) as mentioned in
  the section on the use of CAT5 cable remotely supplies the AP with power
  these can be fitted to a panel (RPP) in the wiring closet to provide a centralised
A fresh look at the provision of bandwidth to a health agency system. This allows for one UPS to supply all AP devices connected to that wiring closet or hub.

Figure 13-2  Integration of Wired and Wireless Networks
The different configurations of wireless LAN are as follows:

- Indoor
  - Access point to mobile device

- Outdoor
  - Point to point
  - Point to multipoint

In the indoor configuration the AP works as a shared hub. This if the AP is connected to a 10Mbs port of a data switch, then if one user is connected they will have the same performance as a wired user (using 11Mb card). As the number of users increase, the performance decreases, as would be the case with users connected to a hub having an uplink to a switch at 10Mbs.

In the outdoor point-to-point, the AP is connected to an Antenna (usually on the roof or high on a wall) giving a clear view of the distant site. The RF connecting cable used should be low loss, and depending on the distance, the antenna gain may need to be increased. A major problem with quoted transmit distances is the difference in transmit power. In the USA the maximum power output is 1W, in Europe the maximum is 100mW thus the expected transmission distance in Europe is less.
A fresh look at the provision of bandwidth to a health agency

Determining the Antenna Locations

Table 1-1: Distances and Line of Sight Clearance (FCC)

<table>
<thead>
<tr>
<th>Data Rate Mbit/s</th>
<th>14 dBi Yagi to 14 dBi Yagi</th>
<th>14 dBi Yagi to 7 dBi Omni</th>
<th>7 dBi Omni to Vehicle-Mount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distance</td>
<td>Line of Sight Clearance</td>
<td>Distance</td>
</tr>
<tr>
<td>11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5.5</td>
<td>5.6 km</td>
<td>9.8 m (33 ft)</td>
<td>2.5 km</td>
</tr>
<tr>
<td></td>
<td>7.9 km</td>
<td>12.1 m (40 ft)</td>
<td>3.5 km</td>
</tr>
<tr>
<td></td>
<td>11.2 km</td>
<td>15.4 m (51 ft)</td>
<td>5 km</td>
</tr>
<tr>
<td></td>
<td>15.8 km</td>
<td>20.3 m (67 ft)</td>
<td>7.1 km</td>
</tr>
</tbody>
</table>

Table 1-2: Distances and Line of Sight Clearance ETSI

Figure 13-3  Link distances in the USA

The distances between the antennae and the data rate for USA and Europe are shown in figures 12-3 and 12-4. When the 14dB antennas are added to both sides, the outdoor wireless configuration is extended to 3.5 miles (5.6 Km) at an impressive 11 Mbps throughput. When combined with any third party 24dB antenna, distances of 25 miles at 11Mbps can be achieved transmitting at USA power levels.
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Table 1-2: Distances and Line of Sight Clearance ETSI

<table>
<thead>
<tr>
<th>Data Rate Mb/s</th>
<th>14 dBi Yagi to 14 dBi Yagi</th>
<th>14 dBi Yagi to 7 dBi Omni</th>
<th>7 dBi Omni to Vehicle-Mount</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>11</td>
<td>5.5</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>7.1 km (4.4 mi)</td>
<td>5.5 km (3.1 mi)</td>
<td>5 km (3.1 mi)</td>
</tr>
<tr>
<td></td>
<td>11.3 m (37 ft)</td>
<td>9.1 m (30 ft)</td>
<td>2.2 km (1.4 mi)</td>
</tr>
<tr>
<td></td>
<td>3.2 km (10.5 ft)</td>
<td>2.2 km (1.4 mi)</td>
<td>5.9 m (20 ft)</td>
</tr>
<tr>
<td></td>
<td>7.1 m (24 ft)</td>
<td>7.1 m (24 ft)</td>
<td>2.5 km (1.5 mi)</td>
</tr>
<tr>
<td></td>
<td>6.3 m (21 ft)</td>
<td>4.1 m (14 ft)</td>
<td>3.4 m (11.2 ft)</td>
</tr>
<tr>
<td></td>
<td>1.1 km (0.7 mi)</td>
<td>1.6 km (1 mi)</td>
<td>1.1 km (0.7 mi)</td>
</tr>
<tr>
<td></td>
<td>4.1 m (14 ft)</td>
<td>4.9 m (16 ft)</td>
<td>4.1 m (13.5 ft)</td>
</tr>
</tbody>
</table>

1 The Yagi antenna must be connected to an Access Point configured with the Hi-Gain matched RoamAbout PC Card.

Figure 13-4  Link distances in Europe

In Europe however the distance when 14dBi antennas are added to both sides, the outdoor wireless configuration reduces to 2.5 Km.

The path loss for free space expressed logarithmically is:

\[ Lp = 32.4 + 20 \log f + 20 \log d \text{  db (f in Mhz, d in Km)} \]

\[ Lp = 36.6 + 20 \log f + 20 \log d \text{  db (f in Mhz, d in miles)} \]
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Bandwidth Calculator for 2.4 GHz System

<table>
<thead>
<tr>
<th>Power</th>
<th>100 mW</th>
<th>Output power of transmitter in Watts if ETSI 100m\</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pout</td>
<td>20 dBm</td>
<td>Output power of transmitted in dBm if ETSI 20 dBn</td>
</tr>
<tr>
<td>Ctx</td>
<td>0.582 dB</td>
<td>Loss in dB of 1 meter of cable at Transmitt side</td>
</tr>
<tr>
<td>Mtx</td>
<td>30 m</td>
<td>Length in meters of Transmitt cable</td>
</tr>
<tr>
<td>Gtx</td>
<td>14 dBi</td>
<td>Gain of Transmitt Antenna</td>
</tr>
<tr>
<td>LP</td>
<td>0.2 dB</td>
<td>Lighting Protection Loss</td>
</tr>
<tr>
<td>PT</td>
<td>0.9 dB</td>
<td>Pigtail Loss</td>
</tr>
<tr>
<td>PD</td>
<td>1.5 Km</td>
<td>Path distance in Km</td>
</tr>
<tr>
<td>Crx</td>
<td>0.582 dB</td>
<td>Loss in dB of 1 meter of cable at Recieve side</td>
</tr>
<tr>
<td>Mrx</td>
<td>20 m</td>
<td>Length in meters of Recieve cable</td>
</tr>
<tr>
<td>Grx</td>
<td>14 dBi</td>
<td>Gain of Receive Antenna</td>
</tr>
<tr>
<td>LP</td>
<td>0.2 dB</td>
<td>Lighting Protection Loss</td>
</tr>
<tr>
<td>PT</td>
<td>0.9 dB</td>
<td>Pigtail Loss</td>
</tr>
</tbody>
</table>

\[
\text{Pl} = 103.522 \text{ dB} \quad \text{For 2.4Ghz} = 100+20\log_{10}\text{PD}
\]

\[
\text{EIRP} = 15.44 \text{ dB} \quad \text{Pout-Ctx-LP-PT+Gtx}
\]

\[
\text{Si} = -86.8218 \text{ dB} \quad \text{EIRP-Pl-Crx-LP-PT+Grx}
\]

<table>
<thead>
<tr>
<th>Rs</th>
<th>-84 dBm</th>
<th>11 Mbps</th>
<th>Reciever Sensitivity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-87 dBm</td>
<td>5.5 Mbps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-90 dBm</td>
<td>2 Mbps</td>
<td></td>
</tr>
<tr>
<td></td>
<td>-93 dBm</td>
<td>1 Mbps</td>
<td></td>
</tr>
</tbody>
</table>

**5.5 Mbps Bandwidth expected**

From table 12-2 it can be seen that cable losses are a major factor and can easily undo the gain of the antenna so it is important to keep the AP as close as possible to the antenna. The Cabletron product the Southern Health Board chose allows this to be easily done, as no electrical power is need at the AP. Having studied these calculations it became obvious that the 7dB antenna on the FECV is only giving a small advantage over the internal card. The solution is to encase the AP in a waterproof box that can be connected by CAT5 cable and the antenna fed by pig-tales, increasing the output by
more than 3dB. This would also apply in any location where an external antenna is required.

It is important to pick a location that has a line of sight to the remote end, even though the system will work with obstructions in the path losses will be greater, as the attenuation for solid objects is greater than in free space.

13.4. Line of Sight

The term line of sight (LOS) means that the two antennae can see each other for our products and distances in use in Europe, this means an observer at one antenna can see all or part of another. True radio LOS may extend beyond the horizon due to radio propagation in the atmosphere being curved.

There are three types of loss on line of sight:

- Refraction in the earth’s atmosphere, which alters the trajectory of radio waves. This alteration is not constant and can change due to climatic conditions. As our links are short for radio links, the effects of refraction can be ignored.

- Reflection from objects, which may be near or far from the direct path. Any large reflecting surface that is parallel or partly perpendicular to the radio signal cause reflections of the radio signal. Examples of reflecting surfaces are buildings with low-emissivity (low-e) glass, crowded parking lots, water, moist earth, moist vegetation, and overhead power or telephone lines. As the signal arriving at the antenna may be in or out of phase with the direct line this can cause major problems especially over large bodies of water.

- Diffraction from objects, which may be near the direct path or beam. The shape of the radio beam, defined as the Fresnel Zone, is widest in the middle. The exact shape and width of the Fresnel Zone is determined by the distance
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between the antenna and frequency of the radio signal. The size of the radius is not based on the data rate and the type of antenna.

Because surrounding objects, such as trees, power lines, and other antennas, seriously reduce efficiency of the antenna, it is very important to mount the antenna as high and clear of obstacles as possible.

When at about 80% of the first Fresnel Zone is clear of obstacles, propagation loss is equivalent to that of free space.

\[ R = \frac{1}{2} \sqrt{(\lambda D)} \]

\( R \): radius of the first fresnel zone

\( \lambda \): wavelength

\( D \): distance between sites

Fresnel Radius Calculation

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Speed of light</th>
<th>Wavelength = C/F</th>
<th>Path Distance</th>
<th>Radius of fresnel</th>
<th>For no effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.48E+09 Hz</td>
<td>3E+08 m/s</td>
<td>0.120714 C/F</td>
<td>3000 m</td>
<td>9.515002</td>
<td>7.612002 m</td>
</tr>
</tbody>
</table>

80% of R 7.612002 m For no effect

Table 13-3 Fresnel calculator

Table 12-3 calculates the widest radius but if there is a building nearer to one side that another we need another calculation.

\[ R = 17.3 \sqrt{\frac{d_1 d_2}{(d_1 + d_2)f}} \]

where d’s are in Km, f in Ghz and R in meters or
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\[ R = 72.1 \sqrt{\frac{d_1 d_2}{(d_1 + d_2)f}} \]

where \( d' \)s are in miles, \( f \) in Ghz and \( R \) in feet

\( d_1 \) and \( d_2 \) are the distance from each antenna to the point of checking or potential interference.

\[ \text{Figure 13-5  Fresnel zone for a radio link} \]

<table>
<thead>
<tr>
<th>( d_1 )</th>
<th>( d_2 )</th>
<th>frequency</th>
<th>Km constant</th>
<th>( d_1 d_2 )</th>
<th>( f(d_1 + d_2) )</th>
<th>( R )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.5</td>
<td>2.5</td>
<td>2.4835</td>
<td>17.3</td>
<td>1.25</td>
<td>7.4505</td>
<td>7.0861183</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>2.4835</td>
<td>17.3</td>
<td>2</td>
<td>7.4505</td>
<td>8.9633095</td>
</tr>
<tr>
<td>1.5</td>
<td>1.5</td>
<td>2.4835</td>
<td>17.3</td>
<td>2.25</td>
<td>7.4505</td>
<td>9.5070254</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2.4835</td>
<td>17.3</td>
<td>2</td>
<td>7.4505</td>
<td>8.9633095</td>
</tr>
<tr>
<td>2.5</td>
<td>0.5</td>
<td>2.4835</td>
<td>17.3</td>
<td>1.25</td>
<td>7.4505</td>
<td>7.0861183</td>
</tr>
</tbody>
</table>

\[ \text{Table 13-4  Fresnel radius at various points on route} \]

In table 12-4 \( d_1 \) and \( d_2 \) are taken as adding up to the direct distance in reality they would add to more than the direct route. For half way in table 12-3 we get 9.515 meters while from table 12-4 we calculate 9.507 meters, which is almost the same. It can be see that at a half kilometre from one end the fresnel radius needed is only 7.08 meters a reduction of more than 25%.
13.5. Turning bridges into routers

The AP acts as a bridge so the two locations have to have devices in the same broadcast domain. The solution used by the Southern Health Board is to connect a LAN router to one side and this port now becomes the default gateway for the remote LAN. To increase the performance from the link, a switch using Virtual LAN (VLAN) software should connect to the remote side. If the port the AP is connected to is in a VLAN, then the amount of unwanted traffic on the link can be reduced. A better but more expensive solution is to connect the remote AP to a LAN router at both sides, which will eliminate all unwanted traffic on the link.

13.6. Putting it all together

As can mentioned the chosen base stations can be power fed remotely so when a new location is being networked only a few cables need be run to prime radio transmission locations, to give coverage where it is needed. Having set up the base stations and the clients tested, the gain can be modified by adding an antenna to the base station. In one of the wings of Cork University Hospital there was a requirement for mobile coverage throughout the wing for bedside work. By extending an existing data point onto the corridor an AP was located above door height, and a laptop on a trolley with a PCMCIA card was used as the MD. The signal covered approximately two thirds of the wing. By installing a pencil type antenna at the AP the coverage was increased, but only by a few meters. Next another pencil antenna was connected to the laptop and the entire floor had coverage except for one room where one particular spot had no coverage. On investigation it was found that the steel structure within the building had two occurrences between the antennae.
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Figure 13-6  Components used for wireless networks

Having put enough APs in place to give coverage to a location, Computers can be networked by inserting PCMCIA cards into them and loading drivers; Printers or devices that do not have drivers for WLANs but connect to Ethernet, can be connected to WLAN client devices to give them radio access.
14. Convergence

Having a wireless network for data wires are not needed at the desk for data services except for power, however if the users need phone connectivity, there are a number of options that do not involve cabling.

Individual portable phones ranging from:

- Super Phone, a large analogue base station and large handset coverage of up to 5 miles
- DECT phones, GSM style handsets with coverage of less than 100 meters

These work well if there are only one or two users, but if the number increases then the number of base stations becomes unmanageable. To overcome this there are two standards to provide base stations with multiple handsets.

CT analogue base stations connected to cards in the PABX and DECT as CT2 but using digital protocol

Nortel have two systems that utilise the above protocol.

- The Meridian Companion CT, which consists of two cards in the Meridian 1 a base station with 2 channel capacity and coverage of up to 200m. The end user uses CT compliant handsets. The base station can be up to 1.2Km from the PABX.

- The Nortel DECT Companion, which consists of the Nortel DECT Mobility Card (DCM), which is similar to an analogue or digital line card and supports up to 32 users. The base station has coverage of 50 to 200m depending on environment and can handle either 4 or 8 channels. The base station can be up to 1.7Km from the DCM. To remove the need for power at the base station the bases can be powered remotely via a remote power interconnect (RPI).
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Rather than build two wireless networks the next step is to integrate them so that one base station is capable of dealing with both services. Rather than having a low bit rate data over the DECT solution, carrying voice over the WLAN network would be a more feasible alternative.

There are three solutions that can deliver this:

- IP Telecommmutor soft phone on the computer and either use the sound card to act as voice codec or use Universal Serial Bus (USB) phones (all from Nortel) this solution was used in the FECV.

- Cisco IP telephony phone (Celcius phones) or Nortel 2004i phone connected to a WLAN client device over Ethernet and working back to an ITG card.

- Symbol / Nortel IP portable phone which uses Spread spectrum technology to connect to an ITG3 card as the IP gateway.

The interconnection of these devices is shown in the figure 13-2. The application server could be a patient information database, information could be accessed by the symbol phones and patients identity bracelets (containing persons name patient number and relevant details) can be scanned.
Figure 14-2 Voice and Data over the one Wireless network

This allows the ultimate in wireless workplace where the only wires needed are for power.

14.1. Future RadioTrends

As the demand for increase in bandwidth new standards are being developed as mentioned earlier, the standard being used by the Southern Health Board is IEEE 802.11b at 11Mb in the 2.4Ghz band. A new standard is being examined IEEE 802.11a at 54Mb in the 5Ghz band. Access devices are being developed by suppliers that will have inbuilt slots to insert cards for 11Mb and 54Mb, this would allow voice to be run over the 11Mb system and data over the 54Mb system. The access points will now have 100Mb copper interfaces, which will remove any bottleneck in the copper network.
By using IEEE 802.11e QoS capabilities and IEEE 802.1x Extensible Authentication Protocol, users accessing the network can be given access and the functionality that they are entitled to. If IEEE 802.11g which is proposed to run at 22Mb in the 2.4Ghz is ratified the dual systems will run even faster.

With the demand for constant communication, the campus user in a location, such as St Finbarrs Hospital, will need to have access to both voice and data services whilst on the campus and not just within each building. This will force data staff not just to place access points where they are easy to install but to plan the layout and integration of both directional and omni-directional antennae.
15. **Comparison with industry trends**

In examining the positioning of the work carried out in relation to the present industry publications whether these be Magazines, Books or Websites. The following sources were used:

**Magazine**

‘Network Magazine where the enterprise meets the new network’ April 2001 Vol 16 No 4.

‘Network Computing’ March 2001 Vol 12 No 6

**Book**


**Website**

[www.cisco.com](http://www.cisco.com)

Network Magazine does a special report on ‘Untangling the local loop’ starting at page 43. This report is, as Gaul, divided into three parts.

- ‘DSL Customer Premises Equipment Get Down to Business’ pp44-48. This article gives both an overview of the technology and a list of the main suppliers in the industry. One of whose (Efficient Networks) equipment has been tested and used by the Southern Health Board. The article gives budget costs for the equipment, which is important for new entrants to the area. The article states that the deployment of DSL is in its infancy and is expected to grow in the ADSL area by two times while the SDSL is expected to increase by 4 times. The work carried out with Efficient/Flowpoint routers and also with the Nokia
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modems has given an understanding of the possible problems and the potential deployment in ‘Business Tenant Services (BTS)’ similar to St Finbarrs Campus.

- ‘Fixed Wireless Services: Wonder or Woe’ pp50-54. This article examines the deployment of wireless in the local loop in the USA. The 2.4 and 5.1Ghz spectrum are mentioned as being potential only until devices fill the spectrum. Here bandwidth in the 10Mbits range or higher, as 4G. DSL and radio technologies, rather than competing, can be used as complementary technologies with radio used in rural areas providing point-to-point links at higher speed than DSL could deliver. A word of caution here is that power output in the USA is higher. Radio can provide cell coverage to mobile users as in Switzerland where an entire town was kitted out with 802.11b access points this is cited in ‘Wireless Ethernet: Neither Bitten nor Blue’ page 126. This type of coverage was given to an area around the FECV.

- ‘The last Five Hundred Miles’ pp56-60. Stated that Satellite communications should be aimed at the local loop rather than the mobile user. This article concentrated on LEO and MEO satellites systems, the only mention of GEO is ‘For comparison, geostationary offers capacities of up to 155Mbits/sec and latency of about half a second but they need big dishes pointed in the right direction’. If one was to focus on the local loop then the once off alignment of a dish is all that is required. DVB developments using a combination of Ku and Ka will deliver speeds surpassing 3G and in the region of 4G bandwidth, so should not be rule out.
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Network Computing magazine does a cover story on

- ‘DSL on the rise’ pp50 - 56 concentrates on the development of DSLAMS and their interoperability.
- ‘Dishing the goods on DSL devices’ pp61 – 66. Concentrates on end user devices again covering the main producers of these devices.
- ‘Voice system overhaul nets wireless, IP and analog’ pp75 – 77 is an article on a company moving to wireless and voice over IP. They adopt plans similar to those mentioned earlier using the Nortel networks, Symbol and Enterasys infrastructure.

Technology Forecast: 2001 – 2003 under the heading ‘Bringing Broadband Service to the End User’ covers DSL, Terrestrial Fixed Wireless, Wireless Local Loop, Satellite and Data-over-Cable. pp 433 – 438. Some of these technologies are expanded on later in the article.

- ‘Wireless Local Area Networks’ pp 517 – 519 gives a very good positioning of the 802.11 technologies and futures.
- ‘Next-Generation broadband satellite systems’ pp 535 – 538 covers satellite futures from an American point of view, the only mention of a tested European system is by ASTRA, the bi-directional version is also mentioned but not the Nera offering. The Lockheed Martin / Via sat systems also demonstrated in Italy are mentioned.
- ‘ADSL in the Central Office’, ‘ADSL Services in the Basement’ and ‘DSL Services at the Pedestal’ pp 570 – 571. Sees the development of mini-DSLAMs either in Basements (building access locations) or into digital loop carrier
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(DCL) pedestals. These developments follow the Southern Health Boards campus solutions. This is also followed up on the Cisco web site.

In viewing Cisco’s web site a white paper on ‘The Service Provider Opportunity for Multiple Dwelling Units and Multiple Tenant Units from Cisco Systems’ was found.

- ‘As the Internet penetrates all aspects of life, owners and managers of multiple dwelling units/multiple tenant units (MDUs/MTUs) find that they can attract tenants if they offer broadband Internet access services. An MDU/MTU is any facility that has more than one tenant, whether business or residential. Examples of MDUs/MTUs include high-rise office buildings, commercial business parks, hotels, university campus dormitories, and apartment buildings.’ The Southern Health Board’s Hospital campi match this criteria, Cisco supports four broad-band architectures for MDUs/MTUs: DSL, cable, wireless, and Ethernet to deliver MDUs/MTUs connectivity if Cisco see this type of development as the way forward, then there is potential for future growth.
16. Conclusion

In this thesis four main topics have been examined namely

The design, building and commissioning of a Forward Emergency Control Vehicle

The use of copper cabling in and between existing buildings on a campus to provide both voice and data services.

The development of a financial tool to ensure optimal purchase of bandwidth from Telecommunications Providers for inter campus communications

The provision of communications over Wireless Systems where copper on the campus or the Telecoms Operators offerings does not give an optimal solution.

It is proposed to look at each of these topics under the following headings:

- What has been achieved
- Problems that exist and how they might be solved
- Future work to be undertaken in the area

16.1. The FECV

The FECV is in use by the Southern Health Board Ambulance Service at major events acting as a command and control vehicle. This will give them experience of setting up and using the FECV before it becomes necessary to use it in an emergency.

This project has been seen as a development from the bottom up with a health agency integrating technologies to provide a working model rather than buying an existing non
specific product. The European Space Agency (ESA) has sponsored the project and a
direct presentation of the project to them will be held in September 2001.

There are still some outstanding problems such as

- The size of the Satellite Dish and the fact that it has to be removed from the
  trailer and manually aligned.
- The inability to use Duplex video to and from the site due to the current lack of
  bandwidth.

In order to solve the problem with the manual alignment of the dish it is possible to
purchase, (at a cost of 50,000 Euros) a satellite dish which can be mounted on the
roof, which will automatically track the required satellite.

The lack of duplex video may be solved when GPRS becomes more widely available
and video over GPRS products are obtainable.

The future development of the FECV would involve the development of a roof
mounted antennae system and the integration of a duplex video system into the vehicle.

The future development of satellite communications for the Southern Health Board
would involve the examination of DVB systems to deliver information to remote
areas.

16.2. The use of legacy copper

The research carried out has shown that it is possible to make greater use of the
existing copper cabling, whether it is CAT5 or Telco Cables between buildings. For
example it is possible using CAT5 cable to deliver 2 Mbps between devices.
Otherwise co-axial cable would have to be installed. The main saving has been in point to point links between buildings where up to 2.5 Mbps of routed IP bandwidth has been obtained. Otherwise fibre would have to be laid and this would not be cost effective for a small number of users.

The main problem with the use of copper is that DSL (unbundling of the local loop) is not currently available as a product or a service within Ireland.

In the future the installation of point to multipoint links using a DSLAM in each campus and the integration of voice over IP to remote users will give a more seamless solution.

16.3. Financial tool

The development of the financial models have enabled the user to simplify the pricing of leased line networks and allow for the easy comparison between different options. Some versions of this model are used by Eircom staff in the pricing of circuits.

The main problem that exists with the financial tool is that each Telecoms provider uses different ways of charging for circuits, therefore it is difficult to have one package that encompasses all.

The future development in this area would be the further development of the package so that on inputting circuit details the carrier with the most cost effective option would be highlighted.
16.4. Wireless LAN

A modelling tool for transmission paths was developed. This allowed the calculation of expected throughput between buildings without having to set up tests for each site. In order to ensure maximum distance / throughput the power at the antennae should be kept as close as possible to the maximum permitted signal strength. Variables such as lightning protection, length of cables, which have an effect on the transmission power, are catered for in the model.

The problem with WLAN systems is their distance limitations especially in Europe where the maximum allowable power output from the antennae is much lower than in the US.

Future work with WLANs will involve researching the migration to 5Ghz systems for point to point links and the second area to be developed is the use of voice over IP in day to day operation from 2.4Ghz base stations.
Appendix A

Operating Manual

For

Forward Emergency

Control Vehicle
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A. Operating Protocol of the FECV

The following is the operating procedure for the emergency services of the

SOUTHERN HEALTH BOARD
AMBULANCE SERVICE

Reference:-  Cork Joint Major Emergency Plan (Issue No. 2)

MAJOR EMERGENCY – STANDARD OPERATING PROCEDURE (SOP)

AMBULANCE CONTROL
CORK UNIVERSITY HOSPITAL

Activation:  On receipt of information suggesting that something “out of the ordinary has occurred” per definition of a Major Emergency, the Duty Controller should follow the following actions/steps.

NOTE:  This information may come from
- Other Emergency Services
- One of our own Ambulances
- Member of the Public

ACTION CHECK LIST

1. If unsure declare “Major Emergency Stand by” □
2. If scale of incident known declare “Major Emergency declared” □
3. Log initial time and details of information received □
4. Open Special Major Incident Log Sheet □
5. Despatch nearest Ambulances □
6. Notify Gardai at Garda Headquarters, Tralee per 999 (if not already informed) □
7. Notify Fire Service per 999 (if not already informed) □
8. Notify the nearest designated Hospital: (Switchboard)
   - Cork University Hospital □
   - Bantry General Hospital □
   - Mallow General Hospital □
9. Transport for Medical Team □
10. Prefix all messages with:
    - Priority – Major Emergency □
11. Notify Support Hospital
    - St. Finbarr’s Hospital, Cork □
    - Mercy Hospital, Cork □
    - South Infirmary/Victoria Hospital, Cork □
Contd/……

12. Notify Ambulance Control, Tralee
   Notify Ambulance Control, Limerick

13. Notify and despatch one of the following nearest available Ambulance Officers to the scene to act as;
   Site Ambulance Officer (SAO)
   Chief Ambulance Officer
   Supervisor, Cork University Hospital
   Deputy Supervisor, Cork University Hospital
   Training & Development Officer
   Supervisor, Tralee General Hospital

14. Despatch FECV to the scene

15. Put all other adjacent ambulances on stand-by for assistance

16. Put Ambulance Control (MWHB) on stand-by to provide Ambulance back-up at scene or provide cover in areas denuded of Ambulances.

17. Alert Voluntary Ambulance Services on stand-by to assist.

18. Alert off-duty Controller Staff and EMT’s to report to Control for assistance as required.

19. Use Tralee Control to assist in alerting other Key SHB Personnel

20. Major Accident Contact List. Refer to attached list and Appendices of Cork Joint Major Emergency Plan.

21. Despatch Ambulance Officer as Liaison Officer at Designated Hospital.

Issue No. 2

PETER CURLEY
CHIEF AMBULANCE OFFICER
On Call Out

- Remove power lead from enclosure in front of vehicle.
- Pull hand break
- Remove parking blocks from between wheels on both sides.

Figure 1  **Towbar connections**

- Reverse 4x4 into position.
- Unlock hitch coupling with blue colour key.
- Drop hitch using dept control handle onto hitch.
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**Figure 2** parts of trailer connections

- Hitch Coupling
- Lock
- Hand break in off position
- Black Cable: Provides lights to trailer
- Red Break cable

**Figure 3** Connected and secured

- Lock hitch coupling using blue coloured key.
- Connect break automatic red cable which will activate if vehicle breaks free.
- Connect rear lights to 4x4.
- Rise front stabilising wheel and lock in position using dept control handle.
- Release hand break.
- Move slowly forward and check lights at rear are working and all wheels are turning freely.
- May now move to site
On Route

- Contact ambulance control to get co-ordinates, easting and northing of location.

![Map of County Cork with coordinates](image)

### Figure 4 Coverage of SHB

- Contact SATCOM Management Centre with location and estimated time of switch on.

On Arrival at Site

- Park vehicle as level as possible, front to rear, and left to right.
- If there is room to leave 4x4 connected, do so.

Else:

- Pull hand break.
- Remove light cable.
- Unclip break safety lead.
- Drop front wheel.
- Unlock hitch coupling with Blue coloured key.
- Raise hitch with handle until hitch coupler comes free from hitch.
- Move 4x4.
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Entering the Vehicle
- Open front door.

![Front door diagram](image)

To open remove lock move clip to left and pull handle

**Figure 5**  Front door

- Unlock using orange coloured key.
- Pull back clip and open with handle.
- Get break blocks and put between wheels.

![Stabilisers](image)

**Figure 6**  Stabilisers

- Get timber supports, place under supports at each side to the rear and secure in place.
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- Vehicle is parked.

**Power up**

- Open Telecom rack with key hanging from rack.

![UPS front panel](image)

**Figure 7 UPS front panel**

- Push "Test" button on front of UPS.
- If dusk or dark, turn on switch no 1.
- If in area where 220v is available, use white extension lead with 13 amp square pins on one end square and blue 16 amp circular socket on the other.
- Plug into blue 16 amp plug in cable enclosure in front of vehicle.
- Now UPS being used to filter power and is also being charged.

At this stage the following are optional:

- PABX
- Mobile interface
- Data Switch
- Spread Spectrum Radio interface
- Users can now begin to use
  - Phones
  - Laptops
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Generator and Satellite System Setup

- Open back door by unlocking lock at back left and back right with green and brown coloured keys respectively.

![Diagram of back door]

To open remove lock raise clip and pull handle

**Figure 8 Rear door**

- Lift both clips and lower back door.
- Remove the generator, move to front of vehicle.
- Start by
  - Moving throttle to START position.
  - Pressing green button.
- Generator starts.
- Connect 16A cable to generator and plug in to enclosure large plug 32A.
- When generator is running smooth and if no 220V available

- Moving 110V 220V toggle switch to 220V position
- Change over load switch in enclosure.
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Figure 9  Change over switch in enclosure

- Now UPS being used to filter power and is also being charged also sockets are being supplied.

Otherwise the generator will feed the sockets on its own.

Satellite Setup

- Remove Satellite dish from vehicle.
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- Move to a south facing level area if possible.
- Point using compass which is stored in rack.
- Level left and right.
- Level back and front using timber blocks in vehicle.
- Connect both cables from the dish to the wiring, enclosure cables and couples are colour coded, red and blue.
- Switch on switch 2 inside vehicle, this powers on satellite equipment.

**Satellite Setup**

Find level a location as possible is found for the dish to be positioned. Make sure there is a clear view to the South. Mark a North South line on the ground before the dish is moved into place. The dish is then moved into place with the rear leg parallel to the North South line.

Make sure the legs are level when all three are level and level with each other. Then secure the frame in place.

Connect the cables to the Dish

Check the receive level

Tilt the dish up until the level starts to fall then tilt the dish down watch the level rise and as it starts to fall stop and back to the highest strength.

Move the dish left right and seeing the level rise then fall and returning to the strongest level as above.

**At End of Emergency**

**Power Down**

- Switch off generator by
  - Moving 110V 220V toggle switch to centre position.
  - Moving trottle to STOP position.
- Remove 32A socket from enclosure, secure to generator.
- Let to cool down.

- Switch off no. 2, this allows satellite dish to be stored
- First remove the red and blue satellite cables from enclosure.
- Wrap about dish stand.
- Place in back of vehicle and secure.
- Turn off switch 1
- Turn off UPS
Connect 4x4

- Reverse 4x4 into position.
- Unlock hitch coupling with blue colour key.
- Drop hitch using dept control handle onto hitch.
- Lock hitch coupling using colour key.
- Connect break automatic red cable which will activates if vehicle breaks free.
- Connect rear lights to 4x4.
- Rise front stabilising wheel and lock in position using dept control handle.
- Release hand break.
- Remove parking blocks from between wheels on both sides and store in vehicle.

Tidy up

- Put generator in vehicle and secure.
- Shut back door and lock both sides.
- Check to see all equipment put away and that the rack and the cabinet locked.
- Shut and lock front door.
- Move slowly forward and check lights at rear are working and all wheels are turning freely
- Return to base.
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On return to base

- Park in space provided
- Put blocks between wheels.
- Pull hand break.
- Remove light cable.
- Unclip break safety lead.
- Drop front wheel.
- Unlock hitch coupling with colour key.
- Raise hitch with handle until hitch coupler comes free from hitch.
- Move 4x4.
- Release hand break if this is not done the break will stick after a few days.
- Connect power from 16 Amp cable to enclosure.
- Open front door.
- Unlock using orange colour key.
- Pull back clip and open with handle
- Check all equipment
- Charge laptops and lamps.
- While this is in process put up the following sign

![NOT READY TO MOVE EQUIPMENT BEING CHARGED](image)

Figure 11 Door sign

On front door.

- When charging is complete all equipment should be stored.
- The sign removed
Appendix B

Setup Guide

For

Forward Emergency Control Vehicle

2
A fresh look at the provision of bandwidth to a health agency

On callout
Disconnect Power from the autoeject on the side panel of 4x4 (power eject will release but flap will knock while travelling if not secured)

On Route
Contact ambulance control to get co-ordinates, easting and northing of location.

Figure 12 Coverage of SHB

Contact SATCOM Management Centre with location and estimated time of switch on.
On arrival

On arrival on site the 4x4 should be parked in an area with a view to the South and as level area as possible.

Earth vehicle by either putting the earth rod under the rear wheel or by inserting it into the ground connect the lead to the terminal on the 4x4.

Connect 220Volts from Mains if at hand
   Connect input circuit breaker to supply power to Clear sockets and UPS.

Remove 12volt lights and LAN antenna from the body of the vehicle
Place on top of Pump up mast and secure.

Connect Brown power connector and LAN cable to interface in side of 4x4
Check VHF / UHF connectivity
If no coverage or poor coverage then the whip antenna should be removed from roof box Key on starting key bunch.

Connect on either side of light cross bar connect to V/UHF front and V/UHF rear
Open rear door move BNC connectors and connect to front and rear BNC positions near radio chargers.

Now VHF/UHF Radios can be tested.
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Start UPS

Connect circuit breaker giving UPS its load

All internal 220volt sockets supplied by the UPS
- LAN
- PABX
- Dect portable
- FAX

Calls can be made over the GSM / PABX connection
If mains 220volts not connected earlier connect Generator
Start by pressing starter
When running smoothly
Operate changeover switch

Satellite Set-up

Position the Satellite dish with rear leg facing North
Level head of dish support

Connect Satellite cables to vehicle (transmit and receive of D160 and receive of the Astra LNB).
Connect receive LNA of the D160 to Spectrum meter
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Set frequency to 960 Mhz press monitor button while on the Analogue Band Voltage
Pan until Cyprus Sat is received on 5 East on Siruis 2

Depress monitor and view spectrum

Maximise signal strength by panning and tilting
if greater than 80% press attenuation of 20 dB
Lower the Dish by one tread turn
Change the monitoring frequency to 1395 Mhz Still on Analogue Band
Monitor Spectrum

Move the dish towards the East
When the expected spectrum is seen press monitor to see if noise is seen
If so you are on 7East

Maximise signal strength on the Spectrum meter
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Connect D160 cables to LNA and 2W Transmitter
Connect meter to Universal LNB check for Astra Spectrum

Connect Astra Cable to 4x4 and LNB
Check input signal on Astra net computer peak by moving LNB

Check have all lights of Skylinx D160 gone green at this stage, if so equipment is working properly

Now a voice and a data Circuit has now been established with Cork University Hospital.
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On Stand down

The above is reversed.

Remove the Satellite cables from 4x4 coil up and remove from Dish
Lower the pump up Mast
Disconnect V/UHF cables from 4x4 and from connection to Antennae
Remove Antennae and place in roof Box
Disconnect the DC Power and LAN cable from 4x4
Remove Head from Mast coil up cable and place in 4x4
Lock mast in position
Disconnect 220volt supply
Disconnect input trip switch
Shut down UPS
Disconnect output trip from UPS.
Connect BNC to roof antennae
Place earth rod in 4x4
Place Satellite and Generator in transport and secure.

On return to base

Connect 4x4 to trickle charge via Auto eject connector on the side.
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Appendix C

Web Cast Guidelines

Web Cast from FECV to Internet over 56K Satellite Circuit
And
Instruction set
The physical connectivity to do a web cast is as follows.

The camera is connected as shown above the one used here is a Sony EVI-G21 [www.sony.com](http://www.sony.com) this has a remote control and is able to zoom and focus on objects. The camera is powered and it provides power to the microphone / headset. A duplex RCA cable is used to carry the Audio and Video to the laptop in this instance a Gateway Solo 9300 with Windows 2000 operating system and software described later.

The laptop connectivity is shown.
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To start real player recording the first is to launch ulead media studio www.ulead.com this interfaces with the laptops audio and video inputs.

The application launches as follows
For the video equipment we use the video standard required is PAL I.

Having set-up the video input the next requirement is to launch ‘Real Producer Plus’ www.real.com
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The choices are given, to test use Record From Media Device, when transmitting use Live Broadcast.

Pass through the next screen.
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The next screen allows information about the file or broadcast.

As we have limited bandwidth the single rate is used.
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Again as we have limited bandwidth the 28K Modem option is the one to use.
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Voice only also conserves bandwidth.

The same goes for video.
In this the file location was as follows.

With properties as follows

When this screen is visible then it is ready to use.
Press Start to Continue.

The differences for a live broadcast are given below.

After the video selection the following option is presented.
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Fill out the form with the IP address server port filename and servers username and password.

The properties of the broadcast are given next.
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This is followed by the starting screen.

Real Player to view
To view the live broadcast or the recorded file Realplayer is launched

In the Location area the pointer to the file or broadcast is entered and the green arrowhead starts the player.
Above is the statistics for the first transmission via satellite from Nadd subject matter local cow herd. Copy of file is stored.
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Appendix D

Configure Guide to

Remote Office

9150
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To configure the remote office the Configuration Manager software is launched as below the software is password protected.

If the password is correct access to the software is allowed.

Connection to a PABX can be either Serial or Telnet as shown below.
Using the Telnet configuration the IP address of the device is entered.

Next the Login in name and password is entered.
On correct login and password the user is able to access the device information.
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The configuration of the device can be retrieved.

Once this information is retrieved the configuration manager can be expanded and any of its sub menus expanded.
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The System Configuration

![System Configuration Diagram]

- Configuration Manager
- 9150 System Configuration
- IP Configuration
- RLC Connection Configuration
- BRI Port Configuration
- BRI Configuration
- Trunk Group Configuration
- DSP Configuration

**SYSTEM CONFIGURATION**

- Unit ID
- Node Name: 9150-FECV
- Time Offset
- Emergency Activation Code: FF [Enable/Disable]
- SIPR Codes:
  - Online: 99 [Paging], 05 [Registration]
  - Offline: 98 [Local Calling], 09 [Unregistration]
- Companding Algorithm: A-Law, International Tones

[Configuration Setup Interface]

- Configuration: Remote Office 100.68.1.40 Board Type: 9150
- Configuration Setup
- View: Default
- Connect: Configuration Wizard
- Status/Log: System Information
- Help: 13:01

246
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IP Configuration

Trunk Group Configuration
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Basic Rate Configuration
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A similar login is used to logon to the RLC card.

IP address and gateway can be entered
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Each port can be configured as required whether having access to main out via ISDN or just local.
And this screen set up the 9150 as a client of the RLC
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A fresh look at the provision of bandwidth to a health agency

When the data Costing software is loaded the user see the following screens:

On clicking on Leased Lines the main customer form is launched

CNAME can be filled in for the project being priced and the exchange from which the circuit is served picked from the drop down menu.
Having picked both exchanges the cet type requires a bandwidth to be picked again from a drop down menu.

Next click on Press to calculate check box and the calculation are preformed. The next screen shown is the first record screen by clicking the Last record button the record is again shown when happy with the result.

Phase 1 Stand Alone to Stand Alone
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Phase 2  Stand Alone to E1

Phase 3  E1 to E1

To save details of the record to the customer table press the Save to file button.

To run a report of CNAME’s the same as the one on screen click on This Cust Report.

The report can be stored to a suitable location for editing it will also auto open the file from its stored location.
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## Abbreviations

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>3G</td>
<td>Mobile Speed up to 2Mb</td>
</tr>
<tr>
<td>4G</td>
<td>Mobile Speed Over 2Mb</td>
</tr>
<tr>
<td>A &amp; E</td>
<td>Accident &amp; Emergency</td>
</tr>
<tr>
<td>AC</td>
<td>Alternating current</td>
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<tr>
<td>ADSL</td>
<td>Asymmetrical Digital Subscriber Line</td>
</tr>
<tr>
<td>AMI</td>
<td>Alternate Mark inversion</td>
</tr>
<tr>
<td>AMI</td>
<td>Alternative Mark Inversion</td>
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<tr>
<td>AP</td>
<td>Access Point</td>
</tr>
<tr>
<td>ATA</td>
<td>Analogue Terminal Adapter</td>
</tr>
<tr>
<td>ATM</td>
<td>Asynchronous Transmission Mode</td>
</tr>
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<td>BNC</td>
<td>Bayonet Network Connection</td>
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<td>BRI</td>
<td>Basic Rate Interface</td>
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<tr>
<td>C/N</td>
<td>Carrier to noise ratio</td>
</tr>
<tr>
<td>CO</td>
<td>Central Office</td>
</tr>
<tr>
<td>CPE</td>
<td>Customer Premises Equipment</td>
</tr>
<tr>
<td>CUH</td>
<td>Cork University Hospital</td>
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<tr>
<td>DAMA</td>
<td>Demand Assigned Multiple access</td>
</tr>
<tr>
<td>DB</td>
<td>Decibel</td>
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<tr>
<td>DECT</td>
<td>Digital European Cordless Terminal</td>
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<td>DP</td>
<td>Distribution Point</td>
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<td>DSL</td>
<td>Digital Subscriber Line</td>
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<td>DSLAM</td>
<td>DSL Access Multiplexer</td>
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<td>DSSS</td>
<td>Direct Sequence Spread Spectrum</td>
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<td>DVB</td>
<td>Digital Video Broadcast</td>
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<td>E1</td>
<td>2Mb interface</td>
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<tr>
<td>EHO's</td>
<td>Environmental Health Officers</td>
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<tr>
<td>EIRP</td>
<td>Effective Isotropic Radiated power</td>
</tr>
<tr>
<td>EMC</td>
<td>Electro Magnetic Compatibility</td>
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<tr>
<td>EMF</td>
<td>Electro Magnetic Force</td>
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<td>EMT</td>
<td>Emergency Medical Technician</td>
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<td>FEC</td>
<td>Forward Error Correction</td>
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<td>FECV</td>
<td>Forward Emergency Control Vehicle</td>
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<td>FEMA</td>
<td>Federal Emergency Management Agency</td>
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<td>FEXT</td>
<td>Far end Cross talk</td>
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<td>FHSS</td>
<td>Frequency Hopped Spread Spectrum</td>
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<td>FSK</td>
<td>Frequency Shift Keying</td>
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<td>G/T</td>
<td>Gain to noise Temperature</td>
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<td>GEO</td>
<td>Geostationery Earth Orbit</td>
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<td>GPS</td>
<td>Global positioning System</td>
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<td>GP's</td>
<td>General Practitioners</td>
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<td>HDB3</td>
<td>High Density Bipolar</td>
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<td>HDSL</td>
<td>High Speed digital subscriber line</td>
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<td>HF</td>
<td>High Frequency</td>
</tr>
<tr>
<td>HPA</td>
<td>High Power Amplifier</td>
</tr>
<tr>
<td>IDF</td>
<td>Intermediate Distribution Frame</td>
</tr>
<tr>
<td>IDSN</td>
<td>Integrated Digital services NetworkDL</td>
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<td>IDU</td>
<td>Indoor unit</td>
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<td>Acronym</td>
<td>Description</td>
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<td>IP</td>
<td>Internet Protocol</td>
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<td>ISDN</td>
<td>Integrated Digital Services Network</td>
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<td>ITG2</td>
<td>Internet Telephony Gateway</td>
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<td>LAN</td>
<td>Local Area Network</td>
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<td>LEO</td>
<td>Low Earth Orbit</td>
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<td>LNA</td>
<td>Low Noise amplifier</td>
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<td>LOS</td>
<td>Line of Sight</td>
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<td>M1020</td>
<td>4 wire line circuit certified to 9600Kbps</td>
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<td>MCP</td>
<td>Main Cable Pair</td>
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<td>MD</td>
<td>Mobile Device</td>
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<td>MDU's / MTU's</td>
<td>Multiple Dwelling Units/Multiple Tenant Units</td>
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<td>MEO</td>
<td>Medium Earth Orbit</td>
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<td>Multiple Shift Keying</td>
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<td>MSP</td>
<td>Miscellaneous Signalling Processor</td>
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<td>NAT</td>
<td>Network address translation</td>
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<td>NEXT</td>
<td>Near end Cross talk</td>
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<td>NMS</td>
<td>Network Management station</td>
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<td>NWHB</td>
<td>Mid Western Health Board</td>
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<td>ODU</td>
<td>Out door unit</td>
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<td>OMT</td>
<td>Orthogonal Mode transducer</td>
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<td>PABX</td>
<td>Private Automatic Branch Exchange</td>
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<tr>
<td>PCM</td>
<td>Pulse Code Modulation</td>
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<td>PHN</td>
<td>Public Health Nurse</td>
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<tr>
<td>PIMS</td>
<td>Patient Information Management System</td>
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<td>POTS</td>
<td>Plain Old Telephone Service</td>
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<td>PRI</td>
<td>Primary Rate Interface</td>
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<td>Phase Shift Keying</td>
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<td>Public Switched Telephony Network</td>
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<td>RADSL</td>
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<td>Remote Power Adaptor</td>
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<td>SHB</td>
<td>Southern Health Board</td>
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<td>SHDSL</td>
<td>Symmetric Higher speed DSL</td>
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<td>SLIC</td>
<td>S-Bus Line Interface Card</td>
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<td>T1</td>
<td>1.5Mb interface</td>
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<td>Time Division Multiplexing</td>
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<td>Television - Video recorder</td>
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<td>VDSL</td>
<td>Very High bit rate DSL</td>
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<td>VHF</td>
<td>Very High Frequency</td>
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<td>VLAN</td>
<td>Virtual Local Area Network</td>
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<td>VOIP</td>
<td>Voice Over Internet Protocol</td>
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<td>VSAT</td>
<td>Very Small Aperture Terminal</td>
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<td>Wide Area Network</td>
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<td>Wireless Local Area Network</td>
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