Radiant Networks Plc

Radiant™ MESH*WORKS*™

System Description

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Important Notice

This document contains preliminary information. Information, data and figures are subject to change without notice. This document is a system overview and is not intended to represent a system specification

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1 Introduction

1.1 Overview

Radiant Networks is the pioneer of a revolutionary broadband fixed wireless access (BFWA) network called Mesh. Over the last eighteen months, Radiant's Mesh proposition has gathered wide market acceptance as the optimal approach to deliver wholesale broadband access services using wireless techniques. In the world of regulation and standardisation, Mesh has become known as multipoint-to-multipoint (MP-MP). Radiant, as the pioneer of Mesh, holds key patents in this technology. Radiant's SME targeted Mesh product is called **MESH***WORKS*™.

The purpose of this document is to provide information regarding the technical aspects of Radiant's **MESH***WORKS*™ solution, to allow evaluation of the benefits that the Mesh approach delivers. This document answers the questions posed by many people: "what is a Mesh system?"

Radiant has gained extensive understanding of Mesh access network design from analysis, modelling and design work over the last four years. It is impossible to capture all of this experience in such a short summary document, however, Radiant would be delighted to discuss any technical issues in more detail. Please feel free to contact Radiant at the address shown on the cover of this document.

1.2 Key Benefits of MESH*WORKS*™

Radiant is the worlds leading supplier of ground breaking wireless Mesh access networks that will revolutionise and redefine broadband service delivery. Core benefits of Mesh include:

- **Exceptional customer reach**. The 360-degree visibility of the nodes provides better coverage growth with fewer seeds and lower deployment costs.
- **Outstanding spectral efficiency**. Delivering more bandwidth from a finite spectrum asset, allowing greater numbers of customers to have access to broadband services.
- **Guaranteed Quality of Service (QoS)**. Enabling the delivery of a broader range of services to generate predictable revenue streams.
- **No 'big bang' re-planning**. Mesh adaptability removes the need to accurately predict customer uptake.

These benefits allow operators to deploy **MESH***WORKS*™ to deliver low risk, high return services.

1.3 The Market Challenge

In recent years, there has been increasing demand for high-speed transmission of large quantities of data. This has been instigated partly because of the spectacular growth in the Internet and the associated World Wide Web. In addition, there are many new emerging mass market applications for high-speed data, including:

- Video/programming on demand
- Home working
- Video-conferencing / video telephony
- Tele-medicine
- Distance learning / educational media
- Interactive television
- E-mail
- Home banking
- On-line games
- LAN interconnect
- Remote surveillance
- Network computing
- Home shopping
- Private networks
- High definition television
- Travel/holiday services

While the Internet has shown spectacular growth, the telecom networks that connect customers are not easily capable of providing the bandwidth that is required to keep up with this growing data traffic demand. Today, telecom access networks are predominately copper based and consequently do not have the capability to deliver high data rates to the majority of users.

The challenge for the communications industry is to deliver access solutions at a low enough risk to enable interactive multimedia applications and other broadband applications to be available to the wider business and consumer market.

1.4 Broadband access networks

The role of the access network, in any communications system, is to link the customer's premises equipment - the telephone handset or PBX in the case of a telephony network - to the operator's main switched trunk network. The access network has also been called the "local loop."

The vast majority of the local loop networks installed are based on copper wire - and are used for plain old voice telephony systems (POTS). Because of the large number of customers on an access network, the provisioning costs of this part of the overall network are critical to the commercial viability of the network as a whole. Hence the historical predominance of copper wire due to its low cost and availability.

The cost/performance trade-off made with copper is such that only a modest data rate is possible to customer's equipment – up to 56 Kbit/s using modem technology. Yet this is still extremely slow when compared with the rates needed for real time, broadcast quality video e.g. 2 – 6 Mbit/s.

Some operators are now offering digital access services using the ISDN. This is principally targeted at business customers who provide the higher revenues required to offset the cost to upgrade the infrastructure. ISDN still uses copper wire technology, and can support between 64 – 128 Kbit/s, again much less than is required for high-quality video.

Similarly, Digital Subscriber Line (xDSL) technologies make use of existing analogue copper wires to deliver up to 6 Mbit/s to customer's premises. However, these technologies have severe drawbacks in that they have limitations on coverage (high data rates are only possible on short lines) and for high data rates they are highly asymmetrical, only delivering the high-speed data in one direction. This makes them suitable only for some of the possible applications. Furthermore, the technology places certain requirements on the copper customer loop, which has lead to significant deployment difficulties in practice.

An alternative is to use other fixed wire access networks such as those laid by the cable television industry (CATV), which typically comprise co-axial cable and optical fibre. In some countries, these are beginning to be used for voice and data transmission. However, the capital costs of establishing and upgrading these networks are substantial. For example, the cost of installing optical fibre access network across the UK is estimated to be in the order of £15 billion. This scale of up-front investment is a disincentive to the deployment of these kinds of broadband networks, and most CATV operators are utilising copper technology in the final connection to the customer to minimise deployment costs.

1.5 Wireless access networks

The idea of using wireless local loop techniques for fixed access networks has been around for many years. sThese are now beginning to form the basis of real operational networks.

1.5.1 Financial attraction of wireless access

The proportion of costs that have to be incurred up front for a wireless access network is a small fraction of those required for an equivalent fixed line network. It is not necessary to incur costs for prospective customers who do not want service (as may be necessary in a fixed line network). This favourable cost structure has attracted operators in a number of countries seeking to establish networks for data transmission (including internet access) and voice telephony based on fixed radio access in the local loop.

Operators can offer service by erecting sufficient numbers of radio masts, or base stations, to provide radio coverage. Initially these can have modest capacity and involve relatively low cost. When a customer is added, the incremental infrastructure costs are the radio transceiver unit for the customer and additional base station capacity. Using a wireless access network, revenue comes on stream after a relatively low level of capital expenditure resulting in a break-even point at much lower market penetration.

Clearly, the financial characteristics of wireless access techniques make them obvious candidates for use in broadband access networks. Indeed, because of the uncertainty of the size of these new markets, the early break-even point is particularly attractive.

1.5.2 Problems with the use of wireless access for broadband

A typical configuration for a wireless access network is a cellular or point to multipoint architecture, that consists of customer units, (either fixed on buildings or mobile), linked to base stations, which in turn are linked to the trunk network. The cellular nature of these wireless access networks stems from the requirement to re-use the same radio frequencies across different parts of the network. Frequencies must be different in the local proximity to avoid interference, but they can be re-used in nearby cells.

Cellular/point to multipoint architecture is illustrated in Figure 1:

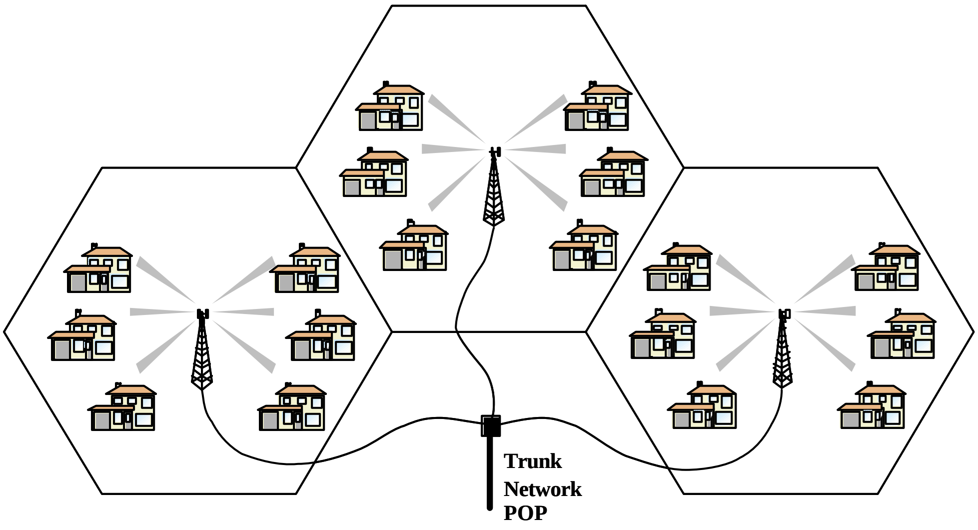

Figure 1- Point to Multipoint Architecture

Cellular or point to multipoint architectures perform adequately for voice and other lower bandwidth services. However, there are significant limitations in the use of such a configuration for broadband purposes; these are related to the use of radio spectrum and the propagation of radio signals.

1.5.2.1 Radio spectrum and bandwidth requirement

The relationship between the speed of data transmission and the bandwidth of radio spectrum used, is complex and depends to some extent on the techniques employed. However, for a given approach, the spectrum required varies proportionately with the speed of data transmission. Typical broadband applications can require data capacities of several hundred times as much as voice applications and thus, using typical cellular telephone techniques, such broadband applications could require hundreds of times more spectrum. For a high performance network, this could require very large amounts of radio spectrum (possibly tens of GHz), which it would be unrealistic to allocate.

1.5.2.2 Line of sight propagation

Even if the requirement were limited to 1 GHz, the only place at present where this is likely to be available is at frequencies that are higher than generally used, probably in the tens of GHz region of the radio spectrum. For example, in the United Kingdom, the Radio Communications Agency (RA) is actively considering the allocation of spectrum in the region of 40.5 to 43.5 GHz for the delivery of broadband data services and, in the United States, a band at 28 GHz has been allocated for similar services.

In these parts of the spectrum, radio propagation becomes “line of sight”, which means that, like visible light, radio waves do not significantly penetrate or go round obstructions. This characteristic imposes further restrictions on the practicality of point to multipoint systems as it becomes difficult to obtain high levels of unobscured coverage without reducing the cell size. Many studies have been carried out to examine the obtainable coverage, and most tend to indicate that about 30-50% penetration is achievable from a single base station in a typical urban environment.

Overlaying the coverage of several base stations in the target area can increase penetration and studies indicate about 60 - 85% penetration is obtainable with overlapping coverage. However, using overlaid coverage to increase penetration has two consequences:

- Firstly, it tends to substantially increase the initial investment, defeating one of the principle attractions of the use of wireless local loop techniques. All of the base stations will need to be in place prior to offering the service. This requires not only a large number of costly base sites, but also fibre connections to each. The cost of this not only increases the initial investment, but also adds to the effective cost per line.
- Secondly, overlapping cells means reducing the spectrum available for a customer connection since the available spectrum has to be shared between the overlapping base-stations, this has a significant impact on overall system capacity

Detailed examination of trade-offs in this type of system has lead to many operators feeling that while it may be possible to financially justify such a system, it represents a difficult investment. This has lead many potential broadband operators to remain cautious.

1.6 MESH*WORKS*™ - A revolution in thinking for broadband radio access

Radiant's **MESH***WORKS*™ system overcomes the conventional drawbacks of point-to-multipoint by employing a mesh structure comprised of customer terminals or 'nodes', which transmit and receive to and from other nodes. Each node can support multiple links and can communicate with other neighbouring nodes. Base stations with their implicit disadvantages are no longer required. Each node supports multiple radio links with narrow beam widths that can be electronically steered in any direction.

The Radiant mesh architecture has significant advantages in terms of cost, capacity and customer penetration; each of which are described in more detail in the following section.

2 MESH*WORKS*™ System Architecture

2.1 Overview

The traditional base-station based approach of PMP systems has shown to exhibit some technical and operational drawbacks. Above 20GHz, signals propagate in a manner very similar to light. This means that to connect a customer, a clear line-of-sight is required between the base station and the customer to ensure a link can be established. This factor has had a major impact on the wide-scale deployment of PMP systems. Furthermore, the inherent spectral inefficiency of existing technologies has limited the scope of deployment that can be supported within finite spectrum allocations.

2.1.1 Mesh – The New Paradigm

The Mesh concept is an inherently simple technical approach. Instead of a series of base stations, each serving a number of remote customers, the customer stations become 'nodes' that are interconnected in a Mesh arrangement. Each node can communicate with several other nodes as well as being able to terminate data for the local user (see Figure 2 below). Data traffic flows over one or more paths between succeeding nodes to reach its destination (so that the radio mesh has some similarities to the structure of the Internet). Traffic flows in and out of the mesh by connecting some of these same nodes to the core network.

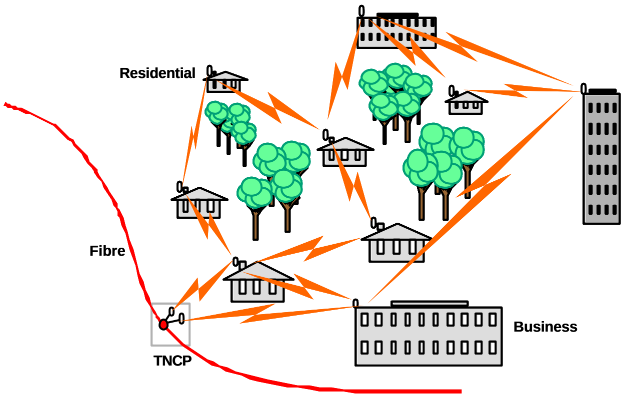

Figure 2 - Mesh Overview

The Mesh architecture pioneered by Radiant Networks is both a logical and a physical mesh. It uses narrow directional radio beams between nodes, rather than using wide-beam antennas (as are employed in PMP base stations and logical meshes). This alternative approach to broadband access has rapidly gained recognition in the industry, and is now generically known as multipoint-to-multipoint. The substantial advantages for operators and users include:

- Significantly improved network coverage, achieving customer reach approaching 100 per-cent;
- Enhanced performance with the potential to be up to 50 times more efficient in its use of spectrum than equivalent point-to-multipoint systems – allowing up to 50 times the aggregate traffic of equivalent PMP systems;
- Economic performance of the network is significantly improved, as no costly base stations are required.
- High resilience and extremely low blocking characteristics due to the inherently redundant nature of alternative routes through a Mesh architecture.
- Very low initial cost of deployment due to the highly scalable architecture.
- Significantly reduced investment risk.

2.1.2 How Does Mesh Deliver Improved Coverage?

Mesh does not alter the line of sight propagation characteristics of radio waves (at the very high frequencies in use), but it does alter the problem. If a new customer is to be added to the system it is now not necessary that they are in sight of a particular base station, but only that they are within sight of at least one other customer. As the customer density increases this probability keeps getting better and better.

An interesting property of Mesh is that good coverage does not require the use of “high sites.” It is no longer necessary to deploy network connection points on the highest buildings or hilltops. The coverage comes from the customers themselves.

Networks are started by the deployment of ‘seed’ nodes, which provide initial coverage. The level of seeding and the deployment process can be optimised to meet the business objectives of the operator. Strategies for seeding include:

- Pre-sell services to create initial coverage when service is “switched on”
- Obtain significant multi-site customers (e.g. schools or health centres) as skeleton coverage

To achieve the initial coverage desired by the operator, a planning tool assists in selecting seed sites. Extensive analysis has shown that a very high probability of connecting a new customer can be reached with a very low density of deployed nodes. Early customers very quickly reduce the need for seeds at all. More importantly, the cost to deploy a seed is an order of magnitude lower than the cost to deploy a base station, which would be the alternative, were a PMP system to be deployed.

2.1.3 How Does Mesh Deliver Greater Performance?

The mesh architecture can be shown to have very high spectral efficiency when compared to an equivalent point-to-multipoint system. This stems from three characteristics:

1. By using narrow point-to-point radio beams, the spectrum can be re-used many more times; energy is not transmitted where it is not needed. The spectral efficiency can be shown to be inversely proportional to the square of the beam-width; halve the beam-width and each frequency can be utilised four times as efficiently. (Point to multi-point systems use wide beam-width sectored antennas.)
2. As customers are connected to their neighbours, the average link length reduces as Customer density increases. This is equivalent to moving from macro cells to micro cells, but without needing the large step change in network design.
3. The redundant nature of data routing through the mesh enables the data capacity to be highly utilised (blocking is reduced). All the bandwidth of the mesh can be shared amongst all of the users, improving the statistical multiplexing advantage.

These characteristics enable the mesh architecture to offer very high levels of aggregate performance when compared to other approaches.

2.1.4 How Does Mesh Deliver Economic Advantage?

When a PMP system is deployed, it has to achieve some minimum start-up coverage. This requires a number of base stations to be deployed. The cost of base stations and their backhaul capacity is high and their locations have to be carefully chosen. Coverage, even to a few sub-scribers, depends on installing a significant number of these base stations, so that an operator is faced with high initial costs when network revenues are lowest.

Mesh has the advantage that coverage comes from the customers and capacity from the network interconnection. Initial deployment costs can be significantly lower for the same or better coverage performance – so allowing the operator to reduce the up-front “risk” capital. It is this reduction in base station deployment, before customers are added to the network, which most significantly affects the operators’ business case. The operator turns its capital investment into profitable revenue more quickly and with less financial risk than with other access techniques.

2.2 The Radiant Node

2.2.1 *Node Overview*

The Radiant Mesh is built entirely from *nodes* that interconnect to form the network. The nodes all use the same basic building blocks, but have slightly different roles. The building blocks are described here.

The Radiant Node is built from a number of key elements, including:

- The Outdoor Unit (ODU) – The fundamental radio product, used in all nodes.
- The Indoor Unit (IDU) – used at nodes where customers require service.

Radiant also offer a number of further elements that extend and enhance the performance of the mesh, some of which are described here.

	IDU	ODU
Design		
Height (mm)	381	820
Width (mm)	51	250
Depth (mm)	216	250
Volume (litres)	4	45
Weight (kg)	5	10

Table 1- IDU and ODU Form-factor

The basic Node configuration is shown in Figure 3 below:

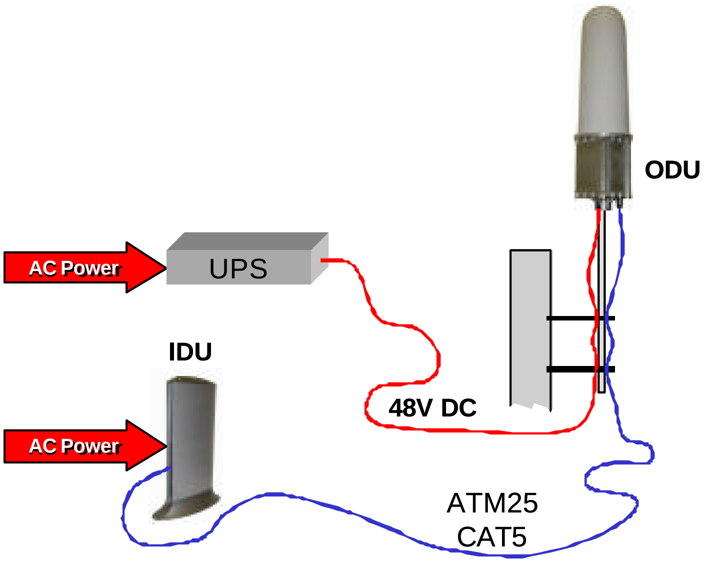

Figure 3 - Overview Node Configuration

Each of the nodes has one or more ODU's and a 48V DC uninterruptible power supply (UPS). The exact configuration of IDU's etc. is determined by the role of the node (See Section 2.3 for details)

2.2.2 The Outdoor Unit (ODU)

The Radiant Mesh Outdoor Unit (ODU) is the high-volume mesh radio, used at all the Mesh Nodes. It provides:

- The millimetric radios, the steerable antennas and the radome;
- The baseband modem and the embedded ATM switch and,
- The host processor running the Node and link management applications

Figure 4, below, shows a functional overview of the Radiant Mesh ODU.

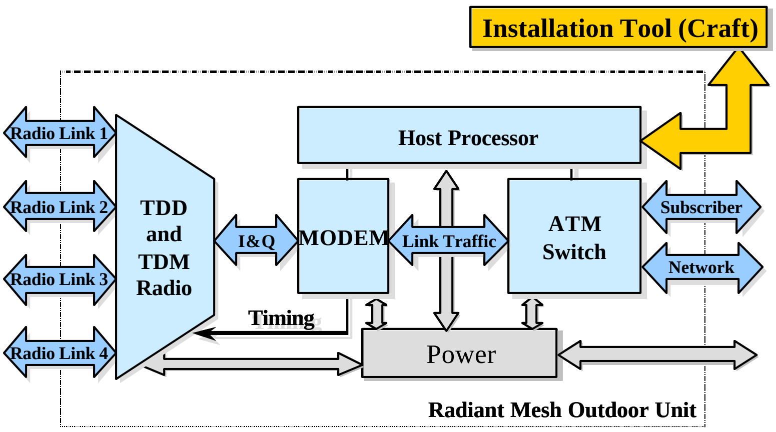

Figure 4 - ODU Functional Overview

The ODU supports four highly directional radio links using a combination of Time Division Multiplexing (TDMA) and Time Division Duplex (TDD) and four individual antennas. The antennas are of a Cassegrain design and are elliptical in profile. This provides an elevation beamwidth of around 9° and azimuth of around 6°. The antennas are steered using stepper motors. These motors have been developed for automotive applications and are therefore designed to operate over a very wide range of environmental conditions.

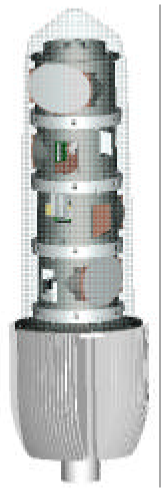

Figure 5 - ODU (Without Radome)

Of the four links at any Node, only a single link is active during any one timeslot, and then only to transmit or receive. This combination of techniques has some significant benefits, including:

- It significantly reduces the overall component count, and hence cost, of the ODU.
- It adds a time dimension, which directly impacts the ability for the Mesh to avoid interference.

The ODU encompasses an embedded ATM switch that enables it to route traffic across the Mesh – the only data that passes between the ODU and the IDU being for or coming from the connected Customer (transit traffic stays on the roof).

The network is built completely from customer Premises Equipment (CPE). The Trunk Network Connection Point (the closest equivalent to a PMP base station in the Mesh) benefits from the same economies of scale that the customer equipment enjoys.

One common reaction to this is that these four-link radios must be more costly than the single-link PMP Customer equipment. It is here that the ingenuity of the Mesh approach becomes apparent. In fact, the four-link mesh node uses time division duplex (TDD) and time division multiplex (TDM) to support four links with one radio. Only one link is active at any time, and then only to either transmit or receive. The sophistication of the node relates to design ingenuity and not manufacturing cost. The antenna gains and the ability to access distant customers via multiple hops means that the power of this radio can be reduced, so reducing the cost of the node compared to a PMP CPE.

2.2.2.1 Modulation and Baseband Processing

The ODU supports three modulation schemes QPSK, 16QAM and 64QAM. These are pre-selected by the Mesh Planning System (MPS) on a link-by-link basis to deliver the availability requirements for the services requested. (Longer links will use lower order modulation schemes, and shorter links can use higher order modulation schemes). The Modem operates at 17.5Msymbols/s.

The TDMA technique means that the radio has a timeslot structure. The radio is pre-programmed to treat a timeslot as either transmit or receive on a specific link at a specific modulation scheme on a specific channel. The task of creating a mesh (ensuring that all nodes in the mesh are correctly programmed to ensure that all the links operate) is performed by the Mesh Planning System.

Each TDMA burst carries a number of Asynchronous Transfer Mode (ATM) cells protected by Reed Solomon Forward Error Correction. The approximate value of the data rates delivered (total transmit and receive) are shown in Table 2, below:

Modulation Scheme	**Modem Burst Rate**	**Total User Transmit and Receive (TDD) bit rate** (Approximate)
QPSK	35Mbit/s	25Mbit/s
16QAM	70Mbit/s	50Mbit/s
64QAM	105Mbit/s	75Mbit/s

Table 2 - Data Rates through the ODU

2.2.2.2 Radio Specifications

The operational frequencies that the ODU uses are determined by the Mesh Planning System and are remotely programmed into the node by the Mesh Management System. The ODU is able to use frequencies across the selected band. Where the spectrum has been licensed as an FDD paired allocation (as is the case in Europe and Japan), the ODU is capable of supporting both upper and lower blocks for its channels in the TDD scheme.

The ODU meets the specifications outlined below:

Item	Specification
Frequency Stability	+/- 15 ppm
TX Power	
QPSK	+18dBm
16QAM	+14dBm
64QAM	+10dBm
Occupied B/W	23 MHz
Error Protection	Reed Solomon
Bit Rate following Error Protection	1×10^{-9}
Antenna Gain	+25dBi (not including Radome)
Polarisation	Vertical
Power Consumption (Total ODU)	<100W

Table 3 - Radio Performance

The ODU has been designed to meet global channel masks, as shown in Figure 6, below.

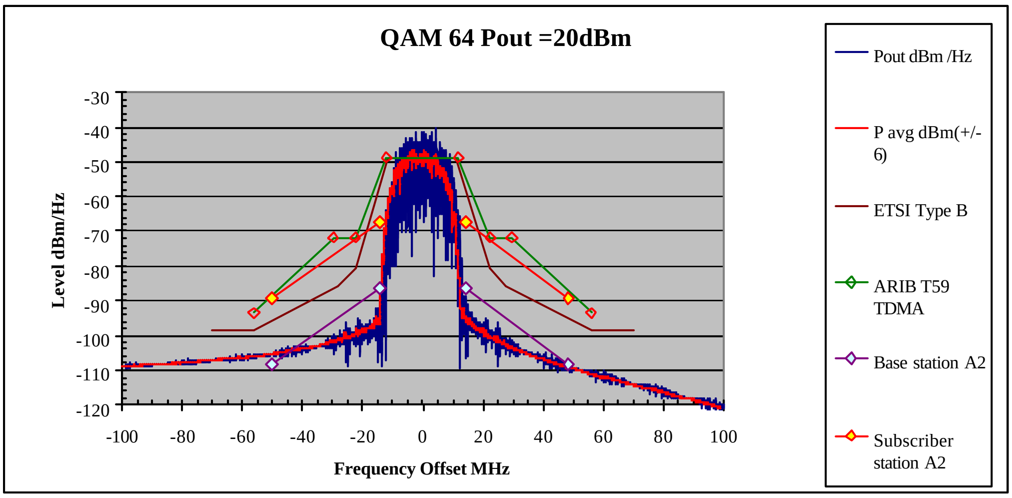

Figure 6 - ODU Channel Mask

2.2.2.3 Mounting and Cables

The outdoor unit is mounted from a 50mm diameter pole. Standard mounting mechanics can be used to mount this on flat roofs or walls. The ODU delivers maximum coverage if mounted above roof height.

The optimum mounting for the ODU requires that it is upright. The ODU itself provides mechanical adjustment to ensure that it is upright. The installer does not need to perform any antenna alignment – antennas are aligned automatically.

The cable between the ODU and the IDU is CAT 5 cable (protected for outdoor use).

The cable between the ODU and the UPS carries power and UPS alarms.

2.2.3 The Indoor Unit (IDU)

The Indoor Unit (IDU) provides the Customer-end adaptation functions. It offers two main services:

- One end of the Mesh edge-to-edge services
- One end of the end-to-end services

The IDU connects to the ODU using a standard ATM25 connection and provides traffic policing and shaping into the Mesh and traffic shaping out of the Mesh. The IDU provides Customers with connectivity to:

- IP Services (Ethernet or USB)
- Optionally, primary rate telephony circuits (E1 or T1)

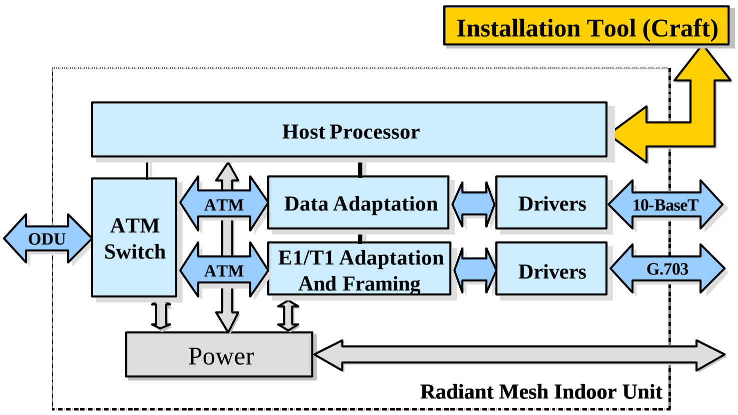

Figure 7 - IDU Functional Overview

The mounting arrangements for the indoor unit can be:

1. Free standing (floor standing)
2. Desktop (flat mounted)
3. Rack mounted (for 19inch rack)

2.2.3.1 IDU Service combinations

The IDU is provided in 2 variants, a full height and half height version. Each IDU variant will be capable of supporting the following interfaces:

Variant	Service combinations
Half Height	1 x USB and 1 x Ethernet.
Full Height	1 x USB, 1 x Ethernet and up to 4x E1/T1.

Table 4 - IDU Configurations

Service combinations will be one of any of the interfaces or a combination of E1/T1 and IP services whilst maintaining the E1/T1 Specification. Different bridged services can be offered concurrently over the Ethernet port.

2.2.4 The Uninterruptible Power Supply (UPS)

The UPS is a separate item from the IDU in the mesh to allow the same UPS to be used in the TNCP, MIP and SEED as at the customer. The ODU may be carrying traffic for other users, so has an independent power backup. The UPS allows the ODU to continue to operate during a short power failure (of the order of a couple of hours, depending on configuration). The UPS does not power the IDU, as it is assumed that the IDU will be backed by the same power management system as the application devices (Servers, PABX's etc.). The UPS provides power status alarms and connects directly to the ODU through a separate power cable.

2.2.5 Other Node Elements

2.2.5.1 Customer Premises Switch

The Customer Premises Switch (CPS) is a low capacity ATM switch that enables a single ODU to support multiple IDU's (up to 4). The planning and management system will configure services through the CPS so that customers have no knowledge that it is present.

By sharing a single radio unit on buildings with multiple tenants (see Section 2.3.3, Customer Nodes), the CPS can reduce the cost per connected customer.

2.2.5.2 TNCP Concentrator

The TNCP concentrator is a low capacity ATM switch that provides a stream aggregation service at the TNCP. This enables the TNCP to use the backhaul fibre (or microwave) capacity more effectively.

2.3 Radiant Mesh System Architecture

Figure 8, below, shows the context of the Radiant Access Network in the complete broadband network proposition.

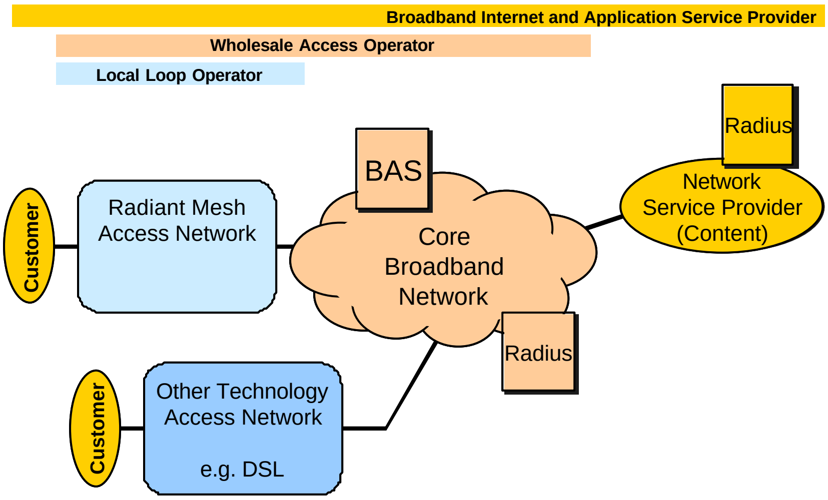

Figure 8 - Access Network Context

The components of the Radiant Mesh are shown in Figure 9 below. The Radiant Mesh is built from nodes, which connect through the infrastructure back to the core network. All the radio elements in the Mesh are fundamentally the same, however they take on different roles within the network. Some provide service to users and others inject capacity into the mesh. Each node consists of one or more of Radiant's standard Outdoor Units (ODU's), which are the radio units for the system. The customers also use an Indoor Unit (IDU), which is the service interface device.

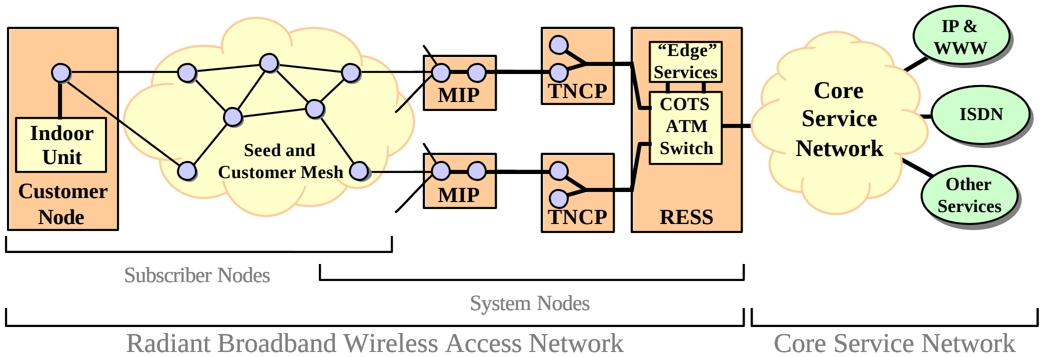

Figure 9 - Mesh Network Architecture Overview

The architectural components of the Radiant Mesh can be categorised as follows (from right to left on the diagram above):

- The Radiant Edge Switching System (RESS) – which provides protection switching and interconnect handoff.
- The System Nodes – delivering the initial coverage and interconnect capacity
- The Customer Nodes – delivering the customer access and additional customer connectivity and capacity.

2.3.1 Radiant Edge Switching System (RESS)

The Radiant Edge Switching System (RESS) consists of a Radiant Edge Processor (REP) and a commercial redundant ATM switch. (The RESS can be considered to be similar to a DSLAM in a DSL access network deployment). The REP is an adjunct to the ATM switch, used at the Mesh interface to the core network. Together, the REP and the ATM switch provide a number of services:

- Aggregation of ATM streams from TNCPs to get maximum efficiency from the available fibre (or other) backbone network
- Shaping and Policing of cells into and out of the Mesh network from and to the trunk network
- One end of the edge-to-edge services.

The RESS itself can be considered to be a peer of the Indoor Unit (IDU) of the Customer Node. Typically, for Phase 1 a RESS will support between one and ten TNCPs. (For residential deployments, the scale of RESS deployed will be determined by the traffic density required). A RESS supports a single logical Mesh of users. Each REP in turn supports one or more Trunk Network Connection Points (TNCPs)

2.3.2 System Nodes

In addition to Nodes deployed at customer premises there is a requirement for a certain number of 'System Nodes' or 'Infrastructure Nodes' in any given deployment. These 'System Nodes' are identical to Customer Nodes but will be configured according to their specific function. There are three types of System Node:

- Trunk Network Connection Points (TNCP)
- Mesh Insertion Points (MIP)
- Seed Nodes

An additional non-radio Element is also used at the point where the Radiant Mesh interconnects with the core network. This Element is called the Radiant Edge Switch System (RESS), and sits at the highest hierarchical level of the Mesh. This is often referred to as the "edge" of the Mesh (hence the name). The RESS provides protection switching and edge-to-edge services across the Mesh.

The Mesh uses ATM switching in every Node to build a physical Mesh network. Customers are allocated Permanent Virtual Circuits (PVC's) over which their services run. Standard ATM adaptation services are used to carry the user services over the provisioned PVC's.

***Note**: The node diagrams that follow here do not show power supply arrangements.*

2.3.2.1 Trunk Network Connection Points (TNCP)

The Mesh needs to be connected to a trunk network at some points, these points are known as Trunk Network Connection Points or TNCPs. The same Node outdoor equipment is used to connect to the trunk network as is used to connect the customer. The bandwidth of a typical connection to the trunk network will be 155Mbps (STM-1). Accommodation of this data concentration is provided by a high bandwidth connection between a TNCP and MIP. Typically, a TNCP would be connected to between 1 and 5 MIPS.

In general, the optimum location for a TNCP will be defined either by the route of an existing trunk fibre or by the ease of laying a cable to the planned site. However, the TNCP locations may not always be at the best location for servicing the maximum number of potential customer sites. For this reason, the Radiant strategy allows for relatively long-distance (4 km) radio links between TNCPs and points at which traffic is distributed into the Mesh, referred to as Mesh Insertion Points (MIPs). These links are known as "long-range" links and use higher gain, manually steered antennas.

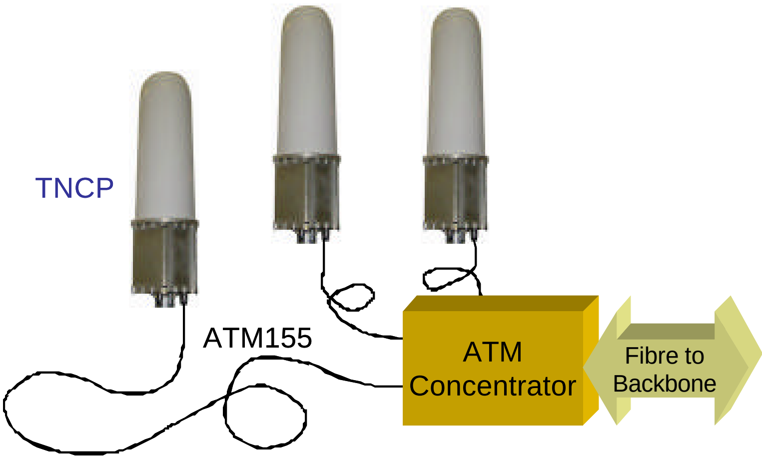

Figure 10 - TNCP Configuration

The actual number of TNCPs needed for any specific segment will be those required to deliver the total peak busy hour traffic into (and out of) the Mesh at the required grade of service (GOS).

2.3.2.2 Mesh Insertion Points (MIP)

A Node can be configured so that all time slots are used on one link. This effectively gives a point-to-point connection of typically 25 Mbps (full duplex). A high-speed link can therefore be established from the TNCP to a MIP as the means of introducing bandwidth into the Mesh. At the MIP two or more Nodes can be co-located and connected together, one configured as the end of the high-speed link to the TNCP and the others as normal Nodes with links to other Nodes in the Mesh. This is illustrated in Figure 11, below.

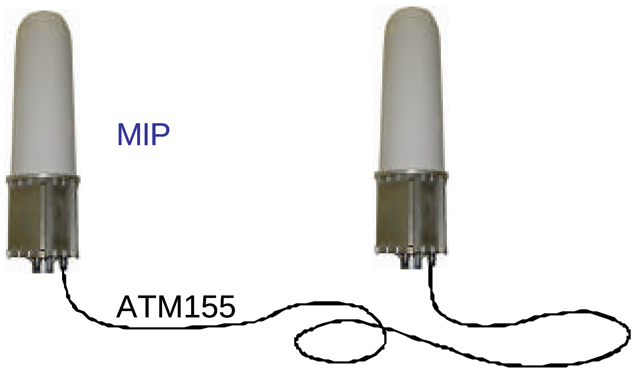

Figure 11 - MIP Configuration

2.3.2.3 Seed Nodes

Unless early customers have visibility of one or two MIPs, it will be necessary to add “Seed” Nodes to provide the necessary access to customer sites. They are positioned simply to provide additional coverage. The Seeds are normal Node ODU’s and are not necessarily linked to TNCPs. There is clearly a requirement that Seeds have to possess a line of sight to at least one other MIP, TNCP or other Seed. The process of “Seeding” a Mesh can be continued until a required level of initial customer reach is achieved; the customer reach being defined as the number of potential customer sites with a direct view of at least one Seed or MIP.

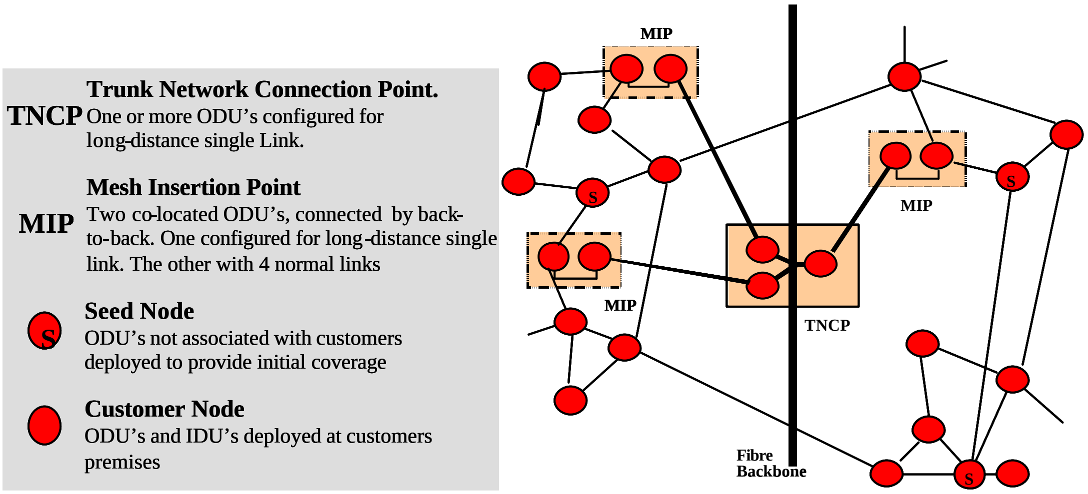

Figure 12 - Radiant Mesh Radio Network Elements

2.3.3 Customer Nodes

The Customer Nodes, the largest number of Nodes within the Mesh, provide both customer access and transit traffic for other Customers. A complete Customer Node consists of the Outdoor radio unit (ODU) and an Indoor Unit (IDU) to provide service presentation.

The MIP and Seed functions can both be converted to Customer Nodes through the addition of Indoor Units, allowing all Infrastructure Nodes to generate revenue if and when required.

The customer nodes can be configured for single tenant buildings or can be extended to support a building with multiple tenants, using a customer premises switch.

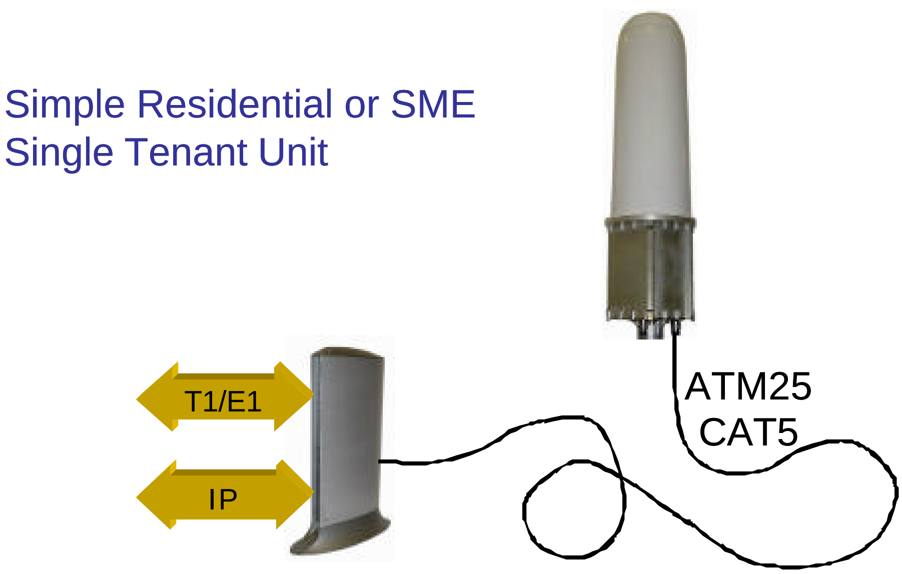

Figure 13 - Single User Customer Node

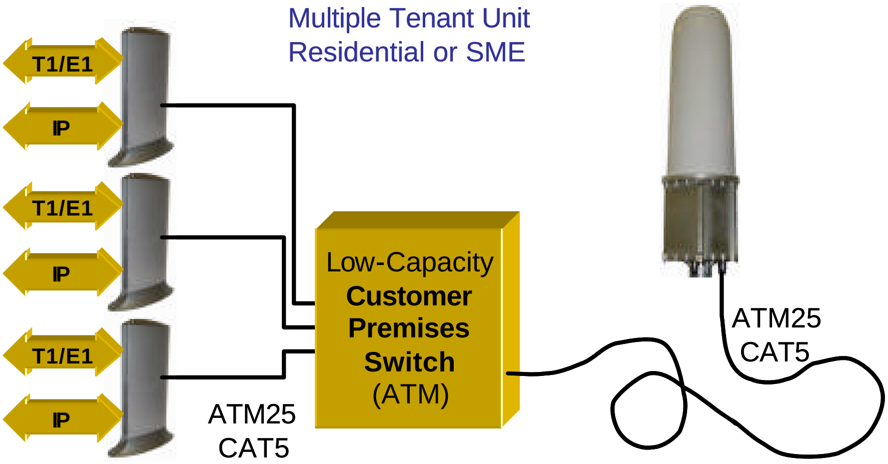

Figure 14 - Multiple User Customer Node

2.3.4 Visibility requirements

A single line of sight to a serviced Node is the only necessary requirement for any Node to form a part of the network. However, there are strong arguments for ensuring that all Nodes should have visibility of at least two other Nodes. This can deliver substantial benefits of performance and reliability. Under these conditions, the network of connections is likely to provide more alternative paths for any connection, allowing more flexibility in responding to high levels of user traffic, as well as providing routes around any single link failure that might occur.

3 MESH*WORKS*™ Services and Interfaces

3.1 Supported Interfaces

The Radiant Mesh provides an extension of the core network across the last mile to the Customer. Interfacing to the Mesh is similar to other access technologies, such as DSL.

The Radiant Mesh has been designed to allow operators to generate revenue from different broadband propositions (see Figure 8 in previous section). Operators can act in different ways:

- a local loop operator (providing a managed broadband connection services to ISPs and OLOs only across the final mile);
- a wholesale access operator (providing services to ISPs and Large Corporates, generally on a wholesale basis for bandwidth between content and Customers);
- a complete integrated service provider (providing content, connection and service management to end users).

The Radiant Mesh is shown in logical overview in Figure 15, below. Interface A represents the interface to the Customer and Interface B represents the interconnect to the core network.

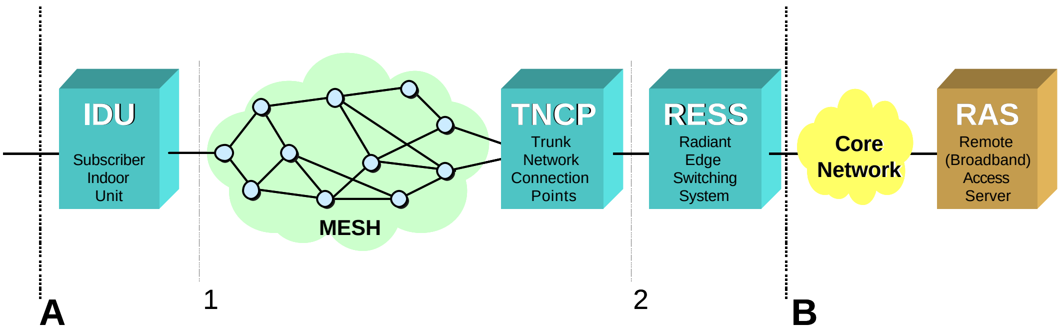

Figure 15 - Mesh Wireless Access Network Overview

3.1.1 Customer Interface

The Radiant Mesh is capable of delivering a full range of broadband services to Customers, both those with constant bit rate time-critical characteristics and variable rate conditions. The Mesh also offers the capability for both symmetric and asymmetric connections. A modular approach has been adopted for the Node interfaces. This allows economic implementation of a range of services across the Mesh. The Node is capable of offering the user a number of different, simultaneous connections.. The Customer interface provides two key services:

- High-speed IP connection.
- Trunk telephony connection.

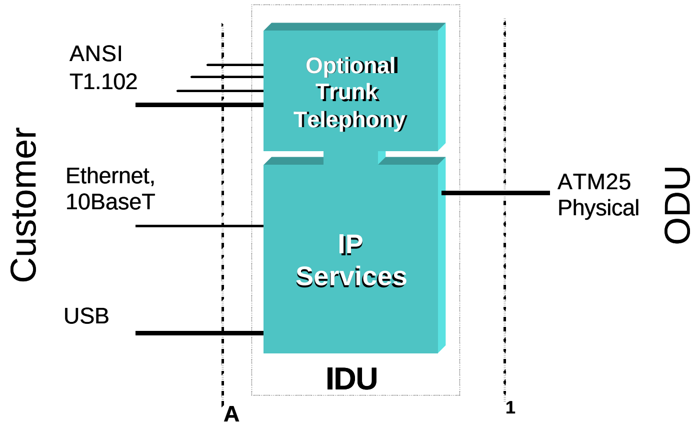

Figure 16 - IDU Interfaces

The interfaces presented to the end user are of the following types:

Interface	Standards	Performance	Number of Interfaces	Physical Connection
Ethernet	IEEE802.3 / RFC2364 / RFC2516 / RFC1483	10/100Base-T	1	RJ45 MDI-X
USB	USB1.1/ CDC1.1/AAL5	-	1	USB type B receptacle
E1 or	G.703/G.704	G.824/G.826	1 or 4	RJ48
T1 (optional)	ANSI T1.102-1993/ G.704	G.824 / G.826	1 or 4	RJ48
ODU	ATM25	-	1	RJ45

Table 5 - Customer Interfaces

3.1.1.1 *Ethernet Interface*

The delivery of Internet Protocol (IP) services is performed using two options:

- Point to Point Protocol (PPP) over ATM
- PPP over Ethernet over ATM

Both techniques are now standardised and are gaining support from a number of prominent equipment vendors. Since PPP is ubiquitous for dial-up remote access, its use can help enhance compatibility with existing equipment and procedures. PPP features such as dynamic assignment of IP addresses, default routers and domain name servers, help simplify remote management. Authentication methods such as PAP and CHAP help maintain security. The protocol stacks for PPP over ATM (using RFC 2364) and PPP over Ethernet over ATM (using RFC2516) are shown below:

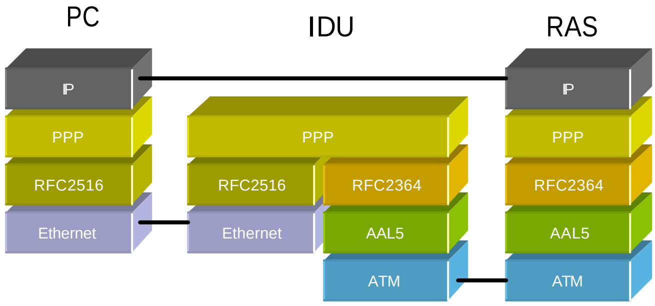

Figure 17 - PPP over ATM

The PPP over Ethernet over ATM model allows multiple PC's to be connected to the IDU via a hub each having its own PPPoE Session. The IDU will conform to RFC1483 and act as a learning bridge, enabling local communication between PC's Connected to a hub.

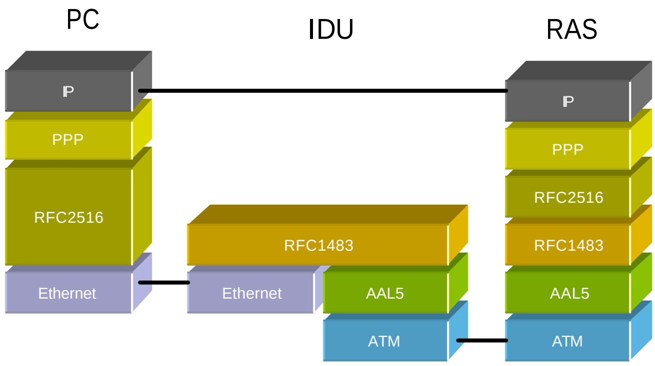

Figure 18 - PPP over Ethernet over ATM

3.1.1.2 USB

The USB presentation consists of a single IP flow from the IDU via a USB port. The protocol stack is shown in Figure 19. The USB interface on the IDU conforms to USB1.1 and CDC1.1. Only AAL5 is supported for the USB interface. The service is available on a standard USB socket.

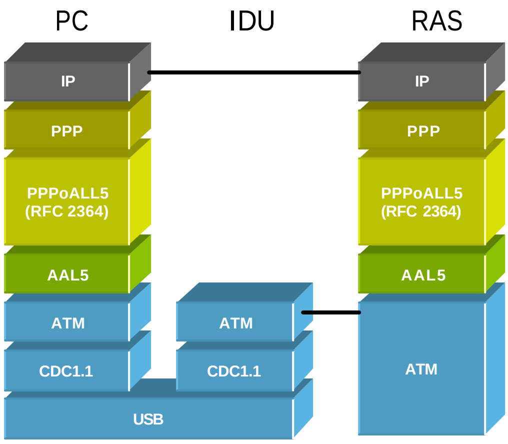

Figure 19 - USB protocol stack

3.1.1.3 E1/T1 Interface

The E1/T1 presentation consists of up to four E1/T1 connections. The protocol stack is shown in Figure 20.

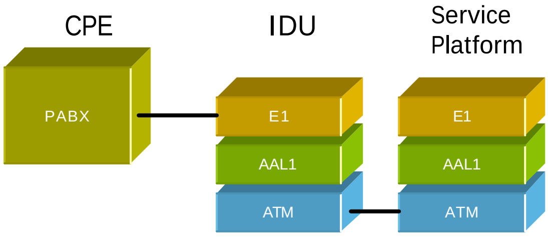

Figure 20 - Protocol stacks for E1

E1 and T1 services are provided using circuit emulation services (CES) as specified by the ATM Forum. Services are delivered as 'nailed up' point-to-point connections using either full or fractional connections. Since the connections are point to point, all switching is performed beyond the edge of the Mesh. The CES allocates bandwidth in increments of 64 kbps up to the full E1 or T1 bandwidth. This bandwidth is pre-provisioned and is allocated whether or not the capacity is in use.

3.1.1.4 Data Rates

Network traffic capacity depends on the physical structure of the Mesh created and on the nature of the traffic flows provisioned across the Mesh. Clearly broad ranges of potential services exist, and it is not possible to specify exactly what services any particular user will require.

Expected performance of the services provided by the Mesh is described below.

The IP service performance can be categorised as follows:

- Ethernet - maximum burst rate: approximately 5Mbps, limited by 10Base-T interface or 25.4 Mbps to and from Customer, with 100Base-T interface).
- USB – Maximum burst rate: is 3-4 Mbps, however this is heavily dependent upon the performance of the PPP stack driving the USB interface.

The Trunk Telephony service is delivered in the following ways:

- Full Structured T1 (1.544 Mbps)
- Fractional T1 (24 x 64kbps timeslots)

3.1.2 Core Network Interface

The Core Network Interface (shown as B in Figure 21 below) is analogous to the interface between a DSLAM and a core network. The interface delivers broadband services carried over a core ATM network.

The network interface is an ATM based connection. Its physical connection is ATM155 (ATM cells at 155 Mbps embedded as a payload in a VC-4 container, in an STM-1 or OC3) conforming to ATM UNI3.0. (As interconnect is through an edge switch, larger deployments can use higher capacity connections if required, OC12 or STM-4).

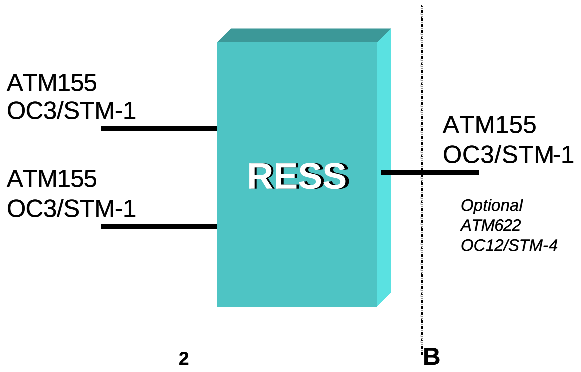

Figure 21 - Core Network Interface

A range of fibre options are available for connection to the core network.

3.2 Supported Services

The Radiant Mesh provides access between the core network and the Customer equipment using standard ATM virtual circuit services (using provisioned Permanent Virtual Circuits, PVC's). This standard ATM service is implemented to offer the full service management features of ATM including:

Variable Bit Rate Services (VBR)	This service supports "bursty" traffic that has a non-real time (nrt) performance requirement. This service is used to transport the IP services across the Mesh.
Constant Bit Rate Services (CBR)	This service provides a guaranteed continuous data rate service with low latency – used to support the E1/T1 services across the Mesh.

Both variable bit rate and constant bit rate services can be delivered to the end user using ATM as the underlying transport mechanism. The Radiant Mesh also allows symmetrical and asymmetrical services to be efficiently supported. When implementing services across the Mesh, different service levels can be deployed.

ATM is the internal transport medium employed within the Mesh to provide end-to-end services with a defined QoS. However, this is transparent to the end user who will see IP and E1/T1 presented as services. Although the backhaul is presented as ATM in an STM-1, the Mesh does not necessarily require the support of an ATM trunk network. The RESS can be connected into a Remote Access Server (RAS) via ATM and then, from the RAS, raw IP or E1 can be extracted. The ATM Paths through the Mesh are calculated and planned by the MPS and implemented within the Mesh by the MMS.

3.2.1 Edge-to-edge services

Edge-to-edge services are those delivered across the Mesh (across the access network). These services are designed to extract additional benefits from the Radiant Mesh.

These services include:

- ATM virtual circuit switching and routing
- Alternative route selection across the Mesh for path redundancy and seamless network reconfiguration
- Traffic Policing and Shaping
- Mesh Redistribution and Adaptation – the service that allows the Mesh to grow as new Customers or services are required

3.2.2 Alternative Path Selection

Each Customer service can be allocated a main and a backup PVC across the Mesh. The RESS and the IDU communicate to determine which path is used. On the failure of the main path between an IDU and its RESS, the alternative can be automatically selected to provide rapid recovery from failures within the Mesh, caused by either link or Node failure.

For this service to be most effective, the alternative routes need to be non-intersecting (in other words pass through a completely different set of switching Nodes and links). The route should use different MIPs and TNCPs. The selection of non-intersecting routes ensures that common-mode failures are minimised, thus ensuring exceptionally good availability performance. A single IDU must use a single RESS, as the RESS offers the connection protection across the Mesh. This means that only the RESS needs to provide particularly high resilience from equipment failure. Other Nodes need only be engineered to provide availability suitable for the customer that is using it.

3.2.3 Policing and Shaping

Different service levels can be deployed when implementing services across the Mesh.. A critical benefit of ATM networks is their ability to support multiple traffic types efficiently. The policing service enables the operator to allocate different service profiles to different users in terms of committed and peak bandwidths.

3.2.4 Path Aggregation

Where variable bit rate services are being used heavily, traffic can be routed simultaneously over more than one path (PVC). The edge function is then one of inverse multiplexing – reconstructing the cell sequence at the Mesh edge (Customer or RESS).

3.2.5 Redistribution and Adaptation

Redistribution and Adaptation are the services that allow Mesh configuration to be modified while it is in operation. It is this process that moves traffic paths within the Mesh, changes timeslot usage or moves links to form new Meshes. Redistribution and Adaptation are performed under management control. This process does not affect service.

4 MESH*WORKS*™ Operator Systems

4.1 Management and Planning Overview

The Radiant Mesh is an extremely flexible system, which enables the operator to select the optimum set of services, performance and deployment options, to accommodate a very wide range of marketing objectives and conditions. However, this very flexibility brings with it a need to have automated assistance in the planning and deployment process. Indeed, at a detailed level (allocation of links, timeslots, frequency planning and routing) it is simply not possible to plan a Mesh manually. Radiant provides a suite of planning and management tools, to carry out these functions. The Radiant Planning and Management Suite is designed to offer a highly integrated Element Management tool set, which will support the Network Operator in achieving his goals, supporting the use of best practice processes to manage networks and services.

When planning a traditional cellular radio network, the planner works significantly ahead of network deployment to determine the coverage and capacity requirements for the network, and to identify key locations and specifications for the base stations to be installed. This planning work involves:

- Selection of base-station or hub sites for coverage
- Frequency planning to avoid interference
- Back-haul network design

These planning processes require assumptions based on market information such as user demographics, target services and Customer penetration targets. The network implementation then follows the plan and the two processes of management and planning are disconnected. The network once implemented is managed "as-is". The planning cycle may be re-visited when capacity or coverage prove not to be optimal, or typically on a quarterly basis.

For the Radiant Mesh, the planning and the management are more intimately connected. The addition of a single customer requires a simple level of planning. The optimum connection can be chosen and the path across the Mesh selected. Once determined, the Management System can then implement the necessary changes to the Mesh to accommodate the new user. Because of this, planning and management are more similar than for traditional networks, and for greatest benefit to the operator, the tools are closely integrated, as is shown in Figure 22 below.

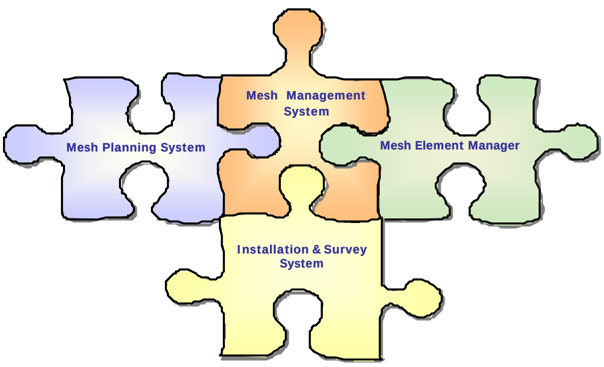

Figure 22 - Radiant Planning & Management Toolset

4.1.1 Planning

The Radiant Mesh Planning system (MPS) supports the establishment of an initial “Seed” network. This promotes the creation of initial Mesh configuration and the installation and configuration of the initial Nodes. Customers can then be added. Each Customer can have a service specification defined (Quality of service, QoS). This service definition includes the definition of Customer services used (E1 or IP) plus the selection of the Committed Information Rate for the service used. The following functions are supported for this planning activity:

- Identify / characterise prospective Customers
- Choose TNCP, MIP and Seed sites
- Design and evaluate a Seed network
- Input operators design parameters and constraints.

Presented with a Mesh change due to addition or removal of Customers, new services or planned Mesh extension, the Planning Tool seeks a way of achieving the target Mesh without violating any of the existing Service Level Agreements (SLAs).

To effectively plan the optimum Mesh, the MPS requires data for the target city. The MPS uses digital elevation maps (DEM) and digital aerial photographs in planning the network. These must be on a 1-metre grid size with 0.2-metre height resolution. The system can also utilise vector data to highlight street and building locations if required.

4.1.2 Management

Mesh properties are very different to those of traditional fixed wireless networks; consequently, a number of Mesh specific features are required within the management tools. The most striking difference is for the Mesh Manager to be aware of, and to visualise the topology of the Mesh at any time., Unlike traditional networks, whose topologies are static (but may have secondary routes), the Mesh topology may be required to change, to cater for additional Customers or capacity demands.

The Radiant Mesh Management System (MMS), although a separate tool from the Mesh Planning System, shares an interest in a great deal of data generated and used by the Mesh Planning tool. The MMS shares access to data with the planning tool in order that it can access vital information about the construction of the active Mesh. Apart from standard functions of fault, configuration, performance and security management, the MMS is also responsible for performing and controlling adaptations to the Active Mesh. The MMS is able to survey potential links within the Active Mesh, as well as testing and measuring the performance of the existing links of the Active Mesh.

The Radiant *Mesh Element Manager* (MEM) provides the part of the architecture designed to give highly scalable deployment - from small to very large. A Mesh Element Manager will control up to a few hundred Nodes, which may constitute a whole Mesh or a part of a Mesh, called a *segment*. If a Mesh is broken down into segments, then a separate Mesh Element Manager will manage each segment. For resilience purposes, each segment can have more than one Mesh Element Manager. The Mesh Element Manager can be considered as a front-end processor or mediation device for the MMS, minimising the traffic requirement on the link between the MEM and the MMS. Communication from the Mesh Element Manager to the Network Elements is achieved using Simple Network Management Protocol (SNMP.)

The Radiant *Craft Terminal* supports both the installation of new equipment and the re-installation / repair of existing equipment. The craft terminal provides functions to support a technician attending the site of installed Radiant equipment, its interface allowing configuration and monitoring of a Device. The Craft Terminal works in co-operation with the MEM to guide an engineer through the installation and configuration of a Node. The Craft Terminal can monitor a Node; this consists of having read access to the MIB of the device it is monitoring. The Craft Terminal also has the ability to perform software upgrades on a Node.

4.1.3 The Platforms

The platforms for the Planning and Management System have been selected according to their operational requirements.

The Mesh Planning System (MPS) is categorised as off-line, low availability, as it does not play an intrinsic part in the day-to-day operation of the network, therefore does not need to be available for the normal running of the network. It is used for planning changes to the network, which can be undertaken off-line and applied whenever the circumstances suit.

The Mesh Management System (MMS) and Mesh Element Manager (MEM) are categorized as real time, high availability, as they play a part in the basic operation and maintenance of the network in order to keep it running smoothly. These elements are not critical to the network delivering service to users; if they fail, the Nodes will continue to work autonomously; however, an operator would loose visibility of the Mesh without these tools.

The Installation and Survey System (which consists of the Craft Terminal and Site Survey tool) is categorized as environmentally rugged as they are to be used by installation and maintenance engineers and therefore are ruggedised for this purpose.

The platforms utilized by the Planning and Management applications are shown in Table 6.

Element	Platform	Operating System
Mesh Planning System	PC	NT4
Mesh Management System	Sun Ultra60	Solaris
Mesh Element Manager	Sun Netra X1	Solaris
Craft Terminal	Hand Held PC	Windows CE

Table 6 - Management and Planning Platforms

Physically, the Mesh Planning System (MPS) and Mesh Management System (MMS) reside on two separate platforms, the MPS on a PC/NT platform and the MMS on Sun/Solaris platform. The two sets of applications communicate where necessary via a common Oracle 8i Database. The Mesh Element Manager is also based upon a Sun/Solaris Platform. See Figure 23 below.

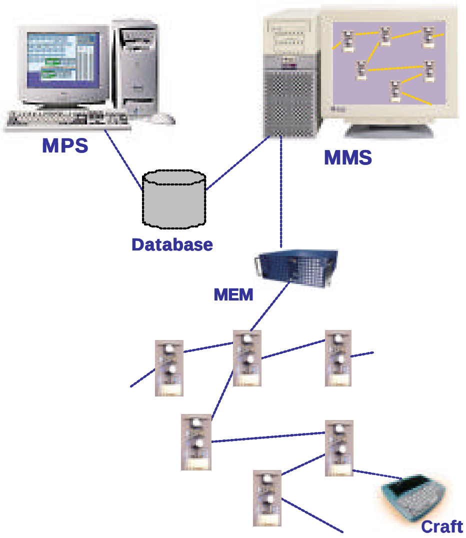

Figure 23- Physical Architecture of the Management System

4.1.4 The Management Architecture

The Management System has a logical architecture that can be simplified into three layers (Figure 24), each with a set of components associated with it:

1. Management Application layer
2. Mediation Layer
3. Managed Elements layer

The MPS and MMS form the Management Application. This layer covers Mesh planning, configuration, fault, performance and security management.

The Mediation Layer is made up of the Mesh Element Manager (MEM) and the Craft Terminal. This layer provides enable the MMS to communicate with the managed elements of the network.

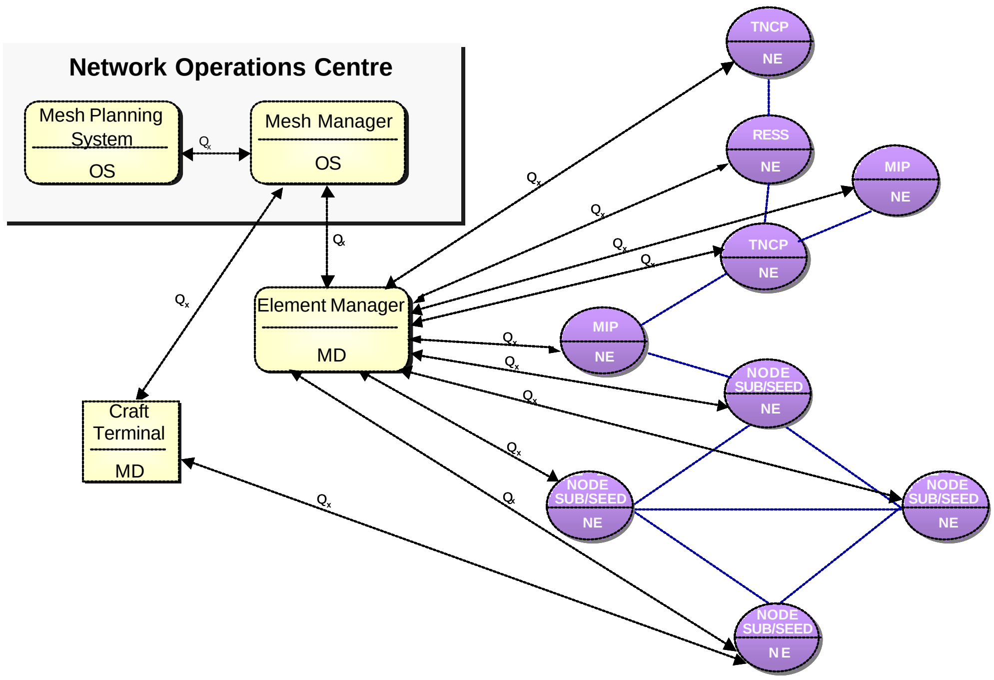

Figure 24- Logical Architecture

The MMS and network elements communicate by using several technologies. The MPS and the MMS are closely linked, the two sets of applications communicate where necessary via a common Oracle 8i Database. For ease of scalability and flexibility, the MPS and MMS communicate via an ORB. Communication with all network elements (RESS, TNCP, MIP and Nodes) from the MEM is achieved using SNMP, this includes all third party elements contained within the Mesh.

4.2 Mesh Planning and Management Toolset

4.2.1 Radiant Mesh Planning System (MPS)

The Mesh Planning System comprises of a set of tools to allow the operator to plan, commission, operate and maintain a Mesh.

4.2.1.1 Service Establishment

The MPS provides support for the prediction of network properties. It excludes any consideration either of an existing Mesh, or of the outcomes of any applications for the use of specific sites. Although a specific deployment of Mesh equipment must be considered, this application of the tool is used only to support general predictions, used mainly for the following activities:

- Business case validation
- Spectrum license application
- Initial Seed network planning
- Planning extensions of the network into new areas

The planning tool holds multiple prospective network models at any one time to allow the comparison of the properties of alternative Mesh layouts. The MPS supports a repeated or incremental process to revisit the design of the Mesh. Each step takes as input the set of sites available to the operator to date (comprising MIPs, Seeds and TNCPs).

Once a network has been designed, the planning tool supports the activities required for turning a scenario into physically deployed and operational equipment.

4.2.1.2 Service Fulfilment

Presented with a Mesh change (due to addition or removal of Customers, new services or planned Mesh extension) this part of the tool set seeks a way of achieving the target Mesh without violating any of the existing SLAs. The complexity of this task depends on the level of synchronized activity allowed, and on the extent of the change. It may range from simply listing all the changes required (to be implemented in a single step) to planning a number of intermediate Meshes, which allow the target to be achieved via a sequence of steps.

To support Mesh change, the planning tool will:

- Predict Line of Site (LoS) from customer premises to existing ODUs
- Identify a set of existing “entry ODUs” with which the new ODU could form links
- Check whether the existing Mesh can both support link(s) to the new ODU and connections of the appropriate bandwidth through to the RESS, without prejudice to existing Customer services
- Determine the appropriate selection of links, timeslots and channels to form a Mesh with the desired characteristics
- Check predicted Customer service parameters (e.g. service resilience) vs. SLA requirements
- Check other Mesh properties vs. minimum requirements
- Determine one or more new Meshes able to provide the required service

4.2.1.3 Service Assurance

A review may be performed for the following reasons:

- Extending the network infrastructure
- Changes to business rules or other operational parameters
- Mesh properties are approaching defined limits
- Environmental change

The service assurance tools are forward planning tools that conceptually are similar to the business planning tools. Instead of assessing network scenarios for business case requirements, where general conclusions are drawn based on a predicted/potential customer population, this tool uses specific parameters that are calculated from an actual Mesh serving a real distribution of Nodes and traffic. The tool can assess issues such as MIP loading, resilience and loading of individual Nodes to allow mesh extension plans to be formulated for the continued growth and success of the Mesh.

4.2.2 Radiant Mesh Management System (MMS)

The MMS, although a separate tool from the MPS, shares a great deal of data that it uses. The MMS shares the database with the MPS so that it can access vital information about the construction of the current Mesh at any time.

4.2.2.1 Service Establishment & Fulfilment

The MMS is responsible for carrying out instructions generated by the MPS to create new meshes. For example, adding new customers into the Mesh or modifying the existing services requires new meshes to be formed. The process of changing the mesh from one form to another is known as Adaptation. The mesh can be Adapted through the application of one or more small changes to the Mesh (each mesh change is in itself a change from one "safe state" to another and each change is atomic). This process is the mechanism to provide new capacity and links for new Nodes or services. Mesh adaptation is performed without affecting services to existing customers on the mesh.

4.2.2.2 Service Assurance

The MMS has standard Configuration, Fault and Performance Management functionality that is associated with typical commercial network management platforms. This allows the operator to have full visibility of the network, with access to Mesh events and access to the configuration data of the Mesh. Unlike typical networks, a Mesh does not have a static topology, as it can change as new Customers are added or removed. The Radiant MMS will always display the topology of the Active Mesh, as it exists at any point in time.

4.2.3 Mesh Element Manager

The Mesh Element Manager (MEM) is used to communicate with a segment of the Mesh. For resilience purposes, each segment can have more than one MEM. The MEM can be considered as a front-end processor to the MMS. It minimises the traffic requirement on the link between the MEM and the MMS. It also acts as a mediation device converting all requests from the MMS from Macro level commands into SNMP commands to configure or retrieve information from Network Elements. Polling is configured by the MMS, but is performed by the MEM. The MEM will also forward any Events generated by the Mesh to the MMS for further action if appropriate.

4.2.4 Craft Terminal

The Craft Terminal, part of the Installation and Survey System, has a variety of functions:

- supporting the installation of new equipment by providing detailed instructions
- repair of existing equipment.
- software upgrades of existing equipment
- Device configuration to the stage where it can communicate with a MEM
- Node monitoring: having read access to the device MIB

4.2.5 Survey Radome

This tool uses an RF method for surveying lines of sight to existing ODUs. The Survey Radome uses radio protocols and RF/modem/management that are identical to those used within a standard Mesh ODU. During installation, a new ODU will scan using one antenna, looking for existing ODUs that are trying to 'bring it into' the Mesh. One or more existing ODUs will be directed by the MMS to point at the new ODU and 'bring it in.' Similarly during survey, the survey Radome scans one antenna looking for existing ODUs that are trying to establish, verify and then drop links to the survey ODU. Once again, these existing ODUs are directed by the MMS.

The Survey Radome will allow the installer to determine a position for locating an ODU such that it will know, to a high degree of certainty, that:

- Usable line(s) of sight exist to other currently installed ODU(s);
- Lines of sight are within the range required to form a radio link;
- Line of sight is at an acceptable inclination to horizontal;
- Having acceptable clearance (grazing or better, depending on the other factors);
- Whether it is too close to a source of interference to permit correct operation;

All of these factors must be known before the installer drills any holes or otherwise modifies the fabric of a building. The absolute position of the survey equipment also needs to be determined and passed to the Network Operations Centre (NOC.) Whilst surveying, a panoramic optical image of the site will be captured (ideally this should be during the summer to take account of any foliage that may exist), looking from the exact location and alignment where the ODU will be placed. This will include a compass reference bearing, and cover the full angle of view that is not impeded by the surface to which the ODU is secured. This image will be stored at the NOC.

4.3 Mesh Tools and the Operational Support System (OSS)

The core purpose of a communications provider is service delivery. The industry is rapidly changing with new rules, competitors, emerging customer sectors, and higher expectations from the end user. The key objectives are faster service introduction and improved quality of service at a lower cost. Achieving these objectives requires well-defined operational support processes, and a strong automated link between the management of customer service offerings and the underlying networking components. The level of automation in the current environment varies. However, for new services and equipment it is essential to provide this level of automation at a relatively early stage of the network evolution. This ensures that there is a means of providing a world-class cost effective service from the Operator to the end user, and from the equipment supplier to the service provider.

4.3.1 Process Model

The Mesh Management and Planning tools will support the Network Operator in achieving its goals, by providing a toolset that can interface (manually or automatically) into the processes used to manage the network. A definition of common processes is shown in the Telecom Operations Map (Figure 25) from the Telemanagement Forum. This uses the layers of the TMN model as core business processes, but divides the service management layer into two parts:

- Customer Care
- Service Development and Operations

In the simplest sense, the division reflects differences between processes triggered by individual customer needs, from those applied to a group of customers subscribed to a single service or service family.

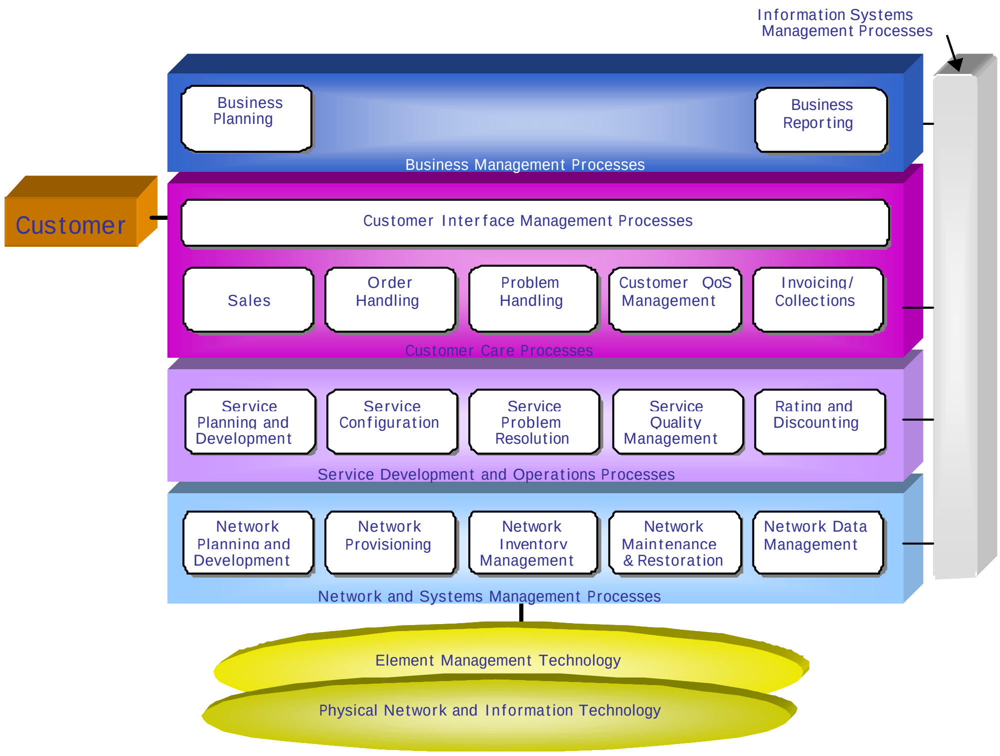

Figure 25 - Telemanagement Forum Process Model

Current interfaces for exchanging management information, on which service and network infrastructure providers depend, can be manual or involve proprietary, low-level interactions. The Mesh Planning and Management Tools will provide a common specification of the interfaces available that will be generic enough to be used by most Network Operators. The interfaces provided are defined based on:

- Identifying process and functional interfaces, particularly all points of contact of the process and its customers
- Identifying control points and critical performance metrics
- Targeting productivity and quality

These interfaces will provide a framework to assess automation opportunities between the existing Operator processes and the Mesh Management and Planning Tools. Candidates for providing an automated interface will be based on:

- Where high repetition of basic information flows is a characteristic
- Where high value is perceived in ensuring rapid reaction
- Where high quality (accuracy and consistency) is required - end customers demand it

The following figure shows an example of the interfaces between the Mesh Planning and Management Tools and the Operator OSS systems during the service fulfilment process.

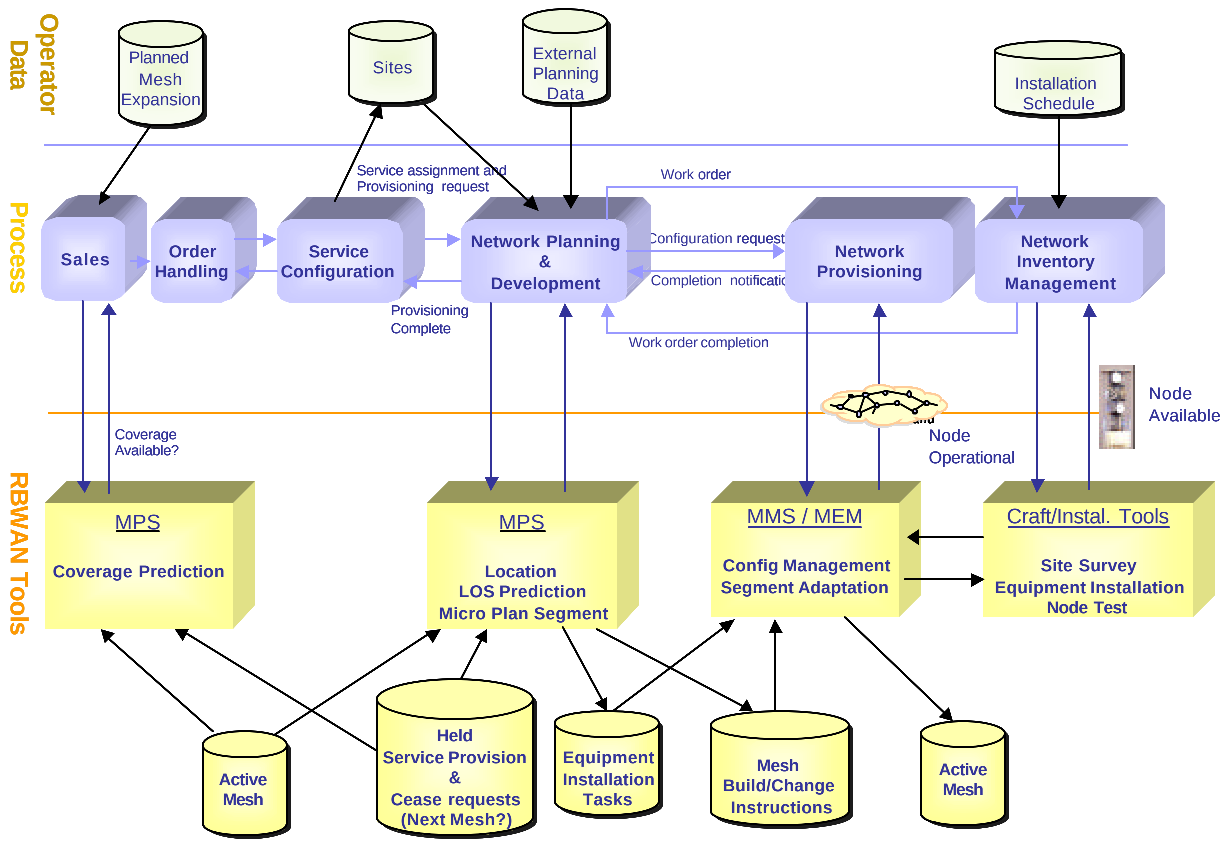

Figure 26 - Service Fulfilment

There are 3 layers presented in Figure 26:

- Operator Data – This represents all data that should be owned and maintained by the Network Operator in order to implement the process described in Layer 2 of the figure
- Process – This layer describes the tasks and communication between tasks to implement the process and the interfaces into the relevant Mesh Tools.
- Mesh (RBWAN) Tools – This layer represents the tools provided by the Mesh and the data that they use or generate as part of the process. This data is contained entirely within the Mesh toolset.

4.4 System Installation

4.4.1 Installation

As Customers become available, the operator will start adding Nodes. To some extent, the number of Customers that will join the network and their required services can be predicted. However, there is no way of knowing the order in which they will join. Other reasons for adding (or removing) Nodes from the Mesh, include:

- Increasing the amount of capacity available
- Redistributing capacity more evenly
- Improving the resilience characteristics of the Mesh
- Free up antennas for new installations by removing links that are no longer needed

Figure 27 depicts the process of adding a new Node to the Mesh. This starts within the sales and order handling process of the Operator, when a customer requests service, and ends in the network provisioning process, with the execution of the Node installation.

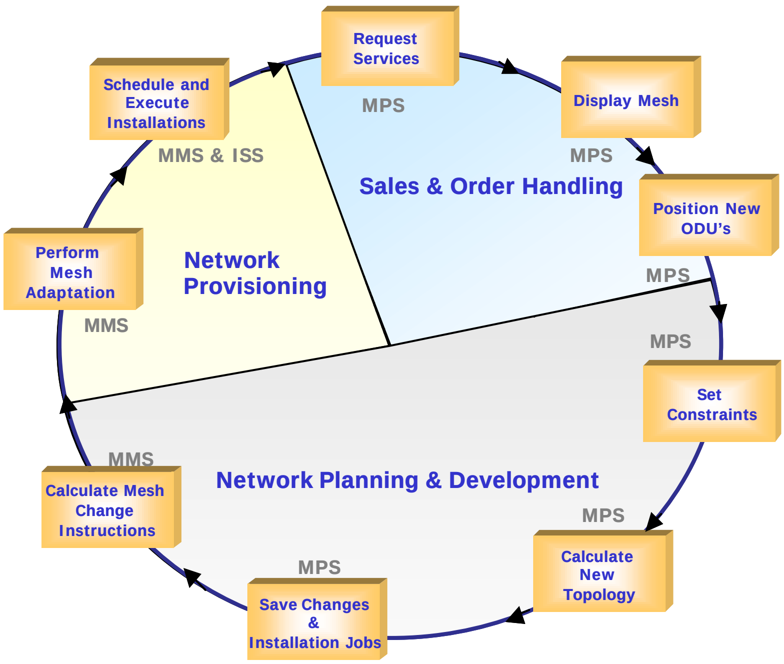

Figure 27 - Service Fulfilment Process

4.4.1.1 Sales & Order Handling

When a new customer requests a service, the Operator must establish that the customer can be connected to the Mesh, and that the requested service can be provided. Given the location of the potential Customer (and using the geographical data and information within it's Database) the MPS will be able to determine the probability that the Customer can be connected.

The Sales process will be informed if there is a line of sight by the MPS, and, based upon the information supplied about the customer location, will be shown a graphical view of the new Node's intended location. This will allow the Operator to verify the location of the customer premises and determine the type of building to be used to mount the Node. Once the building has been identified, the MPS can determine the best roof mounting position, and the service request can be accepted

4.4.1.2 Mesh Planning & Development

When planning a Mesh, constraints can be defined regarding the service that a Customer will receive. The constraints that can be set fall into the following categories:

- Service Provided
- Quality of Service
- Redundancy Options

Constraints can also be set regarding any lines of sight that should or should not be used for a particular Customer, or preferences of which links should be used as primary paths. The planning and design of a network segment includes the following:

- Specification and configuration of network elements to be installed,
- Initial interconnection of these network elements at TNCPs, MIPs and Seed Nodes,
- Interconnection to core networks.

The objective of the process is to produce the detailed design for the network segment that defines precisely how it should be built. The MPS will create objects in its database for devices, services and links. The lines of sight between it and other ODUs in the database are calculated from geographical data. The path chosen will partly depend on the quality of the line of sight and the interference environment, but will also be strongly determined by the distribution of the required traffic capacity. It will also take into account the need to provide backup paths for traffic in the event of equipment failure within the Mesh.

A Mesh configuration is defined that meets the desired criteria for making changes, as well as continuing to support current Customer traffic. It also defines the sequence of configuration changes needed to change the Mesh from the current configuration to the desired configuration

For many reasons, the Mesh segment design may not succeed and a further iteration of site acquisition and planning may be necessary. This process will terminate when the generated network design satisfies the operator. The operator will determine the criteria for this decision. The output of this planning, a detailed design of the Mesh topology and resource assignments, are recorded as Mesh Build Instructions for use by network operations in building the initial Mesh.

If the new Mesh generated meets the criteria set by the operator, the changes to the Mesh and the installation jobs are saved. For each installation job, the order of installation steps is calculated and placed in the databas e, to permit the MMS to schedule and direct each job. The ordering chosen by the planning system ensures that as each device or service is installed, it will be exposed to the network and can be tested. (For example at a new Customer site, an ODU will be installed first and then can be used to connect the IDU into the network.)

The representation of an installation job, as produced by the planning system, provides enough information to direct an installation technician to carry out the installation. The MMS calculates the change instructions required to adapt the current active Mesh to the required Mesh to enable the inclusion of the new Nodes.

4.4.1.3 Network Provisioning

On instruction, the MMS will instruct the Nodes in the active Mesh to perform the changes required to include the newly requested Nodes. The Mesh must be able to support all of the current Customer traffic throughout the sequence of configuration changes, to reach the desired Mesh. It may be necessary for the MMS to construct a set of intermediate Meshes, in order to ensure that none of the existing services within the Mesh are compromised. As each step of the adaptation is performed, the change is tested to ensure that it has been successful; this will include tests for interference. Each action performed on the Mesh is atomic and can be reversed if a problem is detected.

On Adaptation completion, the Operator can schedule the installation of the new Nodes. The installation of the new Nodes will be guided by the installation instructions generated by the MPS during the calculation of the new Mesh (the installation instructions may be used to generate Works Orders for the installation of the Nodes). The adapted Mesh has no dependency on the new Nodes that will be installed and the new Nodes have no dependency on each other, therefore the Nodes can be scheduled to be installed in an order that suites the availability and location of installation engineers.

The Craft Terminal and Survey Radome will aid the installation of the Nodes. The skills required to install a Node in the Radiant Mesh are most closely matched by those of satellite-TV dish and equipment installers. Two main tasks must be performed:

- Positioning and fixing of the Node to a rooftop
- Installation of the indoor unit

Once these two elements have been physically installed, the Node must be configured by the installer, so that it can communicate with the MMS via the Mesh infrastructure. In order to prevent the need for specialized installation engineers this process will be de-skilled as much as possible by the use of the Craft Terminal. Specialist tools will not be required and should be available in the tool kits of most installation engineers.

Node alignment is fully automated, and is under the control of the Mesh Management System. Once the newly installed Node is erected and has been initially configured by the Craft Terminal, the MMS takes control and completes the configuration of the new Node.

4.4.2 Time Budget

Coverage Check - This involves checking for line of sight using the location information provided by the sales operator. This will typically take no longer than a few minutes and could be as quick as a few seconds.

Calculation of a new Mesh – This time is largely dependant upon the size of the Mesh that is being changed. For a small Mesh, it could be as little as a few minutes and for a large Mesh (e.g. 200+ Nodes) typically a few hours. However, the number of Nodes being added to the Mesh will not have a significant effect on the calculation time.

Adaptation – The time taken to complete an adaptation is linked to the amount of change that is required within the Mesh and any existing dependencies, e.g. there may be more than one Mesh created by the MPS that will have to be adapted to achieve a desired Mesh. This is to ensure that there is no service loss whilst the adaptation is in progress. Ideally, this would be scheduled to take place overnight, allowing the daytime hours to be used for Node installation.

Installation – The time taken to install a Node will be comparable with that of a satellite-TV dish and set top box installation. However, the process of positioning the Node needs to be more accurate than that of a satellite dish and the configuration of the Node, although de-skilled by using a Craft Terminal, will be more complex. The service will have to be tested before the engineer leaves. This is especially important if a Customer is connecting a PC and has configuration problems. The testing will most likely be conducted by remotely connecting to a test host for IP services and as a loop back test for E1 services.

4.4.3 Workflow

Service fulfilment is the process of adding and removing Customers from the network, and by implication, handling the issues associated with Customer churn. Due to the innovative approach of the Mesh, this part of the process is different from that of traditional networks; as each Customer is added or removed, the Mesh changes organically each time. This means that the network planning and provisioning process that is normally completed at the establishment phase of the network, continues into the fulfilment stage of the operation, and is a normal part of adding a Customer or changing the service provided. The process shown in Figure 28 provides an example of the workflow required to install a Node into an existing Mesh.

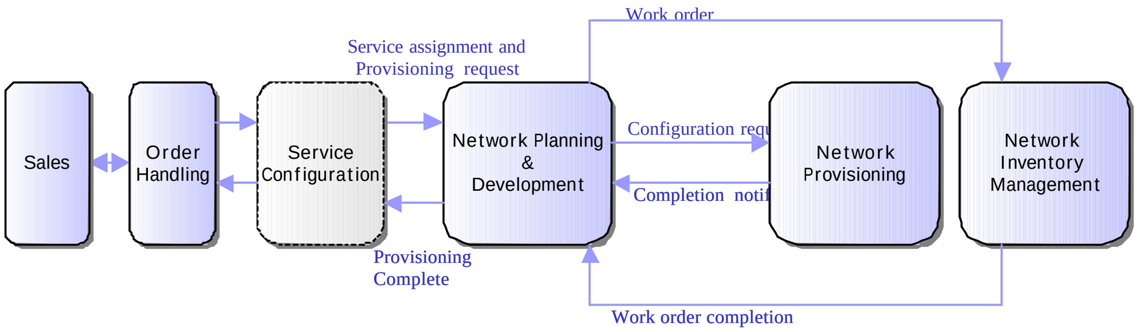

Figure 28 - Service Fulfilment Processes

5 MESH*WORKS*™ System Performance

5.1 Data Rates

The maximum bit rate for a single customer is 25Mbps. This is limited in the extreme by the fact that the interconnection between the ODU and the IDU is an ATM25 connection. The 25Mbps peak data rate is achieved when the Node density means the links are short enough to have an average link performance running at 16QAM.

The Radiant Mesh Nodes each are a single Customer Premises Equipment (CPE). They have a single radio and a single modem. Each Node is only transmitting or receiving in any one timeslot Time Division Duplex (TDD). The radios are Time Division Multiplexed (TDM) across the links; timeslots are used to share the overall bandwidth between the four physical links, so only one link is active (TX or RX) at any time. Each link is pre-planned to use a pre-set number of timeslots each with a planned frequency and each with a planned modulation scheme. The modem supports QPSK, 16QAM and 64QAM. Shorter links can use the higher order modulation schemes. The planning system allocates the modulation scheme that will deliver the requested availability under the specified rainfall pattern.

The maximum bit rate for a single 28MHz channel through a single CPE is approximately 35Mbps of symmetric traffic (or 70Mbps of TX and RX combined, as the Radio only transmits or receives at any one instant of time), when running at 64QAM. This does not answer the total throughput through a channel however, as the key issue of spectral re-use needs to be used to understand exactly the data rates that can be delivered through this spectrum. Therefore, to understand the maximum bit-rate per system, requires more thorough understanding of the spectral efficiency of the Mesh.

5.2 Spectral Efficiency

The Radiant Mesh is highly spectrally efficient. In summary, the spectral efficiency comes from two factors:

- The narrow beam-widths of the antennas, at both ends of the links, provide spatial selectivity on the links and prevent high levels of background interference being generated. The links do not transmit high levels of energy where it is not needed.
- As the Customer density increases, so the average link length reduces. As the link length reduces, the transmit power reduces and so the re-use distance also reduces. The Mesh is adapted as new Customers are added. These Mesh changes are non-service affecting and allow the Mesh to deliver greater levels of spectral re-use, because the average length of links reduces over time.

Analysis shows that Mesh can be up to fifty times more spectrally efficient than a cellular based PMP system.

To understand how much traffic can be passed through a Mesh for a given finite allocation of spectrum, it is then important to understand how the Mesh uses the spectrum. The Mesh Planning System will plan the frequency use of the Mesh to avoid interference, and this is just one parameter that the Mesh can utilise to avoid interference. There are three dimensions for interference avoidance available to the Mesh:

1. **Spatially** The first option is to attempt to select the appropriate link directions where the antenna field of view does not generate unnecessary interference. An advantage of Mesh is that, unlike PMP systems where Customers always connect to hubs, there are many possible ways to interconnect Nodes, and some generate less interference than others. The MPS utilises knowledge of link interference to select the most appropriate pattern of connections.
2. **Temporally** The second option is to try to select appropriate use of timeslots so that Nodes, which fall in the beam-width of one antenna, do not use the same timeslots as one another. However, as Customer density rises, it may not be possible to achieve this.
3. **Spectrally** The third option is to select an alternative channel so that interference is avoided. In this way, it is clear that the use of spectrum is considerably different to that for PMP systems. For PMP systems – spectrum drives throughput and is determined by a relatively static frequency re-use pattern. In Mesh, spectrum allows interference avoidance, and therefore each Mesh configuration is selected optimally by the MPS.

To understand the throughput of the Mesh, it is important to understand what the spectral efficiency delivers - that is Node Density. More channels allow the system to support higher densities of Customer Nodes at the same high service rates.

Analytical modelling of a typical 28GHz licence (even allowing for guard bands) shows that a Mesh could deliver of the order of hundreds of Customer Nodes per square kilometre at a simultaneous average data rate of the order of 2Mbps downstream and upstream. This equates to >400Mbps/km^2. This is the order of traffic required to access a residential service with a realistic economic penetration.

By way of a comparison, a PMP system with an assumed 2.8km cell-radius would deliver 20Mbps/km^2. The Mesh represents a 20-fold increase in spectral efficiency over this PMP system. To achieve a similar level of final network traffic to the Mesh, the PMP system would need to be deployed with a cell-radius of the order of 600m (0.6km). With the spectrum available, this deployment would need to be planned at this scale from day one. For full details, please refer to the appended document: “Mesh Performance in Finite Spectrum.”

Capacity Increase

The principle capacity increasing mechanism is network adaptation. This process allows an existing Mesh to be altered remotely, without any customer’s service being affected. This process allows the link, timeslot and frequency characteristics to be altered over time to take advantage of possible new Meshes as new Customers are added. It can be considered to be like moving from Macro to Micro cells in a mobile network. The network can be reconfigured and the customers are unaware of the process. Through this process, additional customers added to the Mesh have the effect of reducing the average link length, so allowing higher rate modulation schemes to be used.

Total Mesh capacity can be scaled over time through the addition of new TNCPs. Existing Customers or Seeds can be converted to MIPs, and all users can benefit from the additional capacity that is added in this way.

The ODU can use different channel frequencies on each link if required, to avoid possible interference with other links in the Mesh. Each link can also be configured for the most suitable modulation, selected from QPSK, 16QAM or 64QAM, based on link lengths, signal strengths and interference conditions.

5.3 Co-existence Performance

The total system performance will be also be affected by other spectrum licence users. These users, if using systems that generate greater levels of interference, can reduce the performance of all systems deployed. These factors require a clear understanding of the co-existence issues that exist between co-channel and adjacent channel systems. Co-existence performance is now well understood for different types of systems and is documented in the recommendations for regulators laid down by the IEEE – "Recommended Practice for Co-existence of Fixed Broadband Wireless Access Systems". The results are summarised here.

5.3.1 Co-Channel Systems

In the case of co-channel systems, this identifies where other operators holding the same spectrum in an adjacent area may cause interference, so sterilising an area that cannot be served.

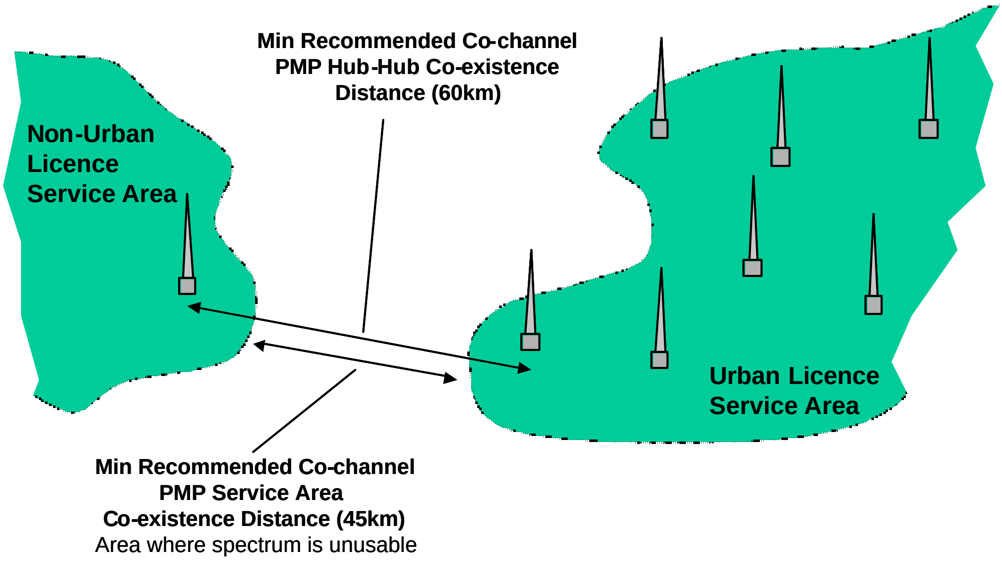

Figure 29 - Co-Channel Re-use distance with PMP to PMP systems

Best practice today shows that where co-channel allocations are awarded, then PMP systems should be separated by a distance of approximately 60km hub-hub or 45 km between service areas, see Figure 30, above. This means that neither party (sharing the same spectrum allocation) can use the licensed co-channel spectrum in the intervening "no-mans land". This obviously means that there are potentially large areas where the proposed spectrum cannot be fully utilised if PMP technology is used.

Co-existence modelling work shows that a Mesh system can be operated at a distance of approximately 12km from a co-channel PMP hub. This obviously means, should a Mesh system be used, that the "no-mans land" would be significantly smaller. (see Figure 30 below).

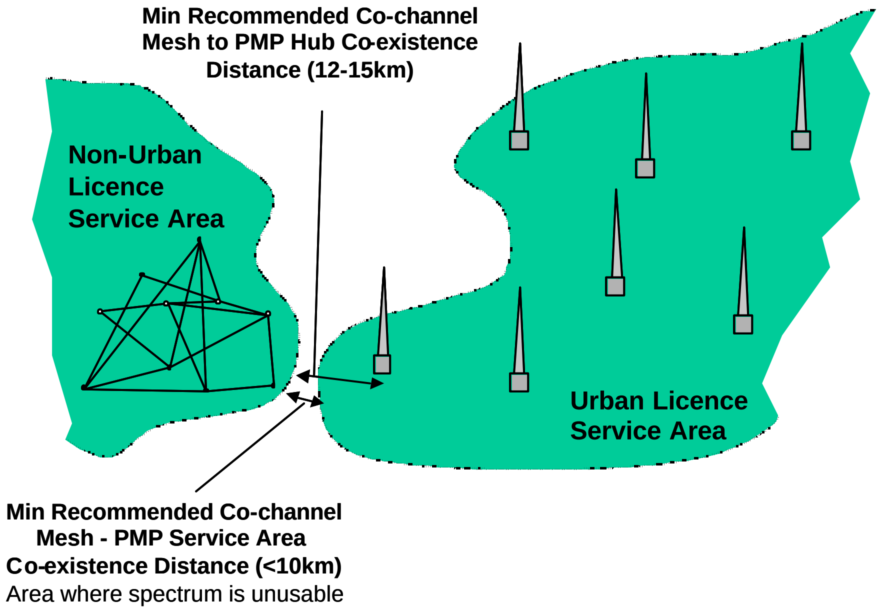

Figure 30 - Co-Channel Re-use distance with Mesh to PMP systems

Co-channel interference with Low Earth Orbit (LEO) satellite systems is difficult to predict, as exact specifications of satellite systems, their installation and expected density is undefined. It is likely that their most common locations will be in sparsely populated areas. However, they are not limited to this application, and it is possible that these terminals will be located on the same, shared buildings as other FWA terminals. For this reason, the shared (co-channel) satellite bandwidth is probably a small risk, but one that no technology can analyse in terms of overall impact on co-existence.

5.3.2 Adjacent-Channel Systems

Adjacent channel co-existence looks at the interference generated by co-located operators who are using adjacent spectrum allocations. TDD PMP systems require double the guard bands of FDD systems, so reducing the spectral efficiency. It is this reason that has lead many regulators around the world to block the use of TDD PMP systems.

Extensive modelling has shown that the Mesh system can happily operate with a single guard channel between it and the neighbouring system. This provides better spectral efficiency than TDD-PMP systems.

5.4 Link Range

In a PMP system, a customer will be either in or out of range of the base station. Further, the environment may mean that a base station that is in range is out of sight, and a line of sight base station could be out of range. With Mesh systems, link range is far less important than with a traditional PMP system. A Customer does not need to be in range of a base station, rather it needs to be in-range of at least one other Customer. If the operator is able to increase their penetration over time, then link range becomes less of an issue as the network grows.

What this means is that link range actually determines the initial start-up characteristics of the mesh, rather than the service area covered. It has an impact on the seeding density required to deliver the mesh performance wanted. Radiant has performed extensive modelling, which has shown that up to a certain link length, increasing the length reduces the seeding requirement. However, extending the link length beyond this limit has diminishing returns, owing to the line of sight restrictions (the longer the link, the lower the probability of a line of sight being available).

Link range is dependant on the modulation scheme used. The Mesh Planning System automatically allocates the highest order modulation scheme that can be used to provide the target link availability. In ITU rain region E, typical link ranges are 3 km for QPSK, 1.3 km for 16QAM and 500 metres for 64QAM for a 99.99% availability.

Summary link budget calculation for 24.5 GHz

	Modulation			
	QPSK	16QAM	64QAM	
Transmitter				
Power	18	14	10	dBm
Antenna gain	22.2	22.2	22.2	dBi
Radome loss	-0.5	-0.5	-0.5	dB
Receiver				
Sensitivity	-79.2	-71.0	-63.7	dBm
Antenna gain	22.2	22.2	22.2	dBi
Radome loss	-0.5	-0.5	-0.5	dB
Link length	3195	1352	480	m
Path loss	-140.6	-128.4	-117.1	dB
Link margin	0.0	0.0	0.0	dB

Summary link budgets for 29.5 GHz

	Modulation			
	QPSK	16QAM	64QAM	
Transmitter				
Power	18	14	10	dBm
Antenna gain	23.8	23.8	23.8	dBi
Radome loss	-0.5	-0.5	-0.5	dB
Receiver				
Sensitivity	-79.2	-71.0	-63.7	dBm
Antenna gain	23.8	23.8	23.8	dBi
Radome loss	-0.5	-0.5	-0.5	dB
Link length	2949	1379	534	m
Path loss	-143.8	-131.6	-120.3	dB
Link margin	0.0	0.0	0.0	dB

In each case, the link budgets highlighted include margins for filter loss, modem implementation margin, etc.

5.5 Mesh Coverage

Unlike traditional point to multipoint networks, the coverage of a Mesh grows as more customers are connected to the network. Coverage in this context is driven by the need to have a line of sight path to another Node in the network.

In a point-to-multipoint system, for a customer to be connected to the network, they have to have a line of sight path to a specific node in the network (the basestation). The probability of this occurring is driven by the local topography and demographics. It may be possible to increase the probability of line of sight by mounting the basestation higher or by planning the network to use a number of overlapping basestations. This second approach has a negative impact on spectral efficiency.

With Radiant Mesh, a customer can be connected to the network if it can see any other Node in the network. Therefore, if there is a high enough density of deployment, the probability of line of sight can be very high indeed.

Since the coverage of the network grows as customers are connected, it is possible to design an initial network with a relatively low line of sight probability. Probability of line of sight increases very rapidly with small increases in Node density, which means that coverage percentage increases rapidly as initial customers are connected.

It is possible to plan the network to ensure that a Node has to be able to see two other connections before it can be accepted onto the Mesh. This can ensure that route diversity is provided to all Nodes. This obviously will decrease the percentage coverage.

Figure 32 shows how coverage grows as node density increases. This is based on analysis of European cities. The shaded area shows the results of modelling on coverage. This band reflects typical coverage probabilities with connection to one other Node being the upper limit of the band and connection to two Nodes being the lower limit.

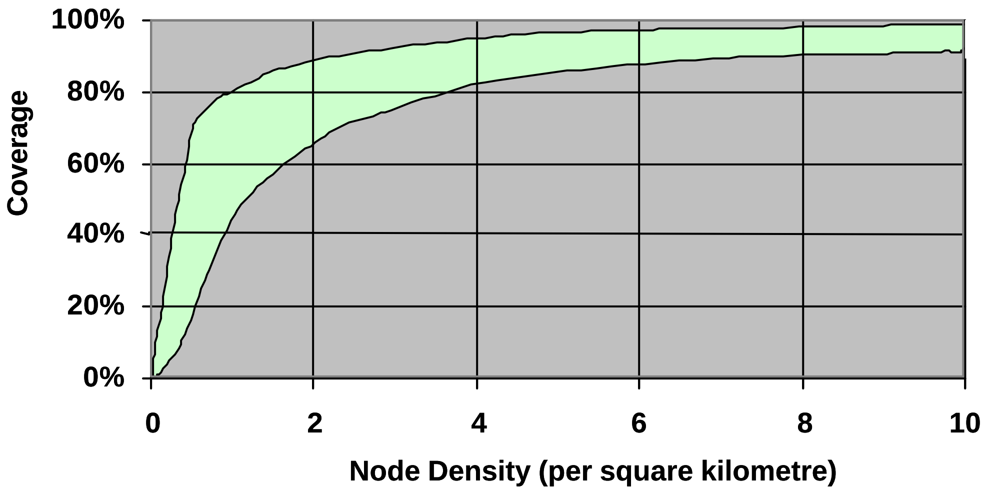

Figure 31 - Coverage Growth Vs Customer Growth

It can be seen that coverage can approach 100% at reasonably low densities of users and certainly can exceed 90% at a density of around 3 Nodes per km2. This compares favourably with typical coverage of 30 to 50% for a PMP system in a similar operating environment.

Installing Seed Nodes within an area would typically provide the initial coverage. Seed Nodes are outdoor radio units with no customer connection. Using 'friendly' customer sites such as schools or multi site businesses could also provide Seeding. As Seed Nodes do not require any connection to wired networks, their deployment in advantageous sites to boost coverage is much more straightforward than deploying PMP basestations.

5.6 Reliability

The availability of services delivered across the Mesh access network is driven primarily by the Customers own equipment reliability. For those customers wanting higher availability, the planning system will attempt to plan primary and secondary routes across the Mesh so that single Customer becomes reliant on their own equipment and not on any other single item. This includes selection of alternative MIP and TNCPs for primary and secondary traffic where these are available.

This redundancy process is a considerable benefit over PMP or traditional Pt-Pt links, where a more serial reliability model is prevalent.

The designed mean time between failures (MTBF) for the Mesh Nodes is ten years, allowing 99.99% service availability to be provided, through an eight-hour operator call out and repair process. Higher levels of availability could be offered to some customers by providing redundant equipment at their site. As the Mesh is inherently distributed in architecture, the availability of the system as a whole improves as more Customers are added, as more options for re-routing become available.

The MTBF target for the infrastructure (RESS and backhaul) can be selected based on the desired availability for services required. The ATM switch core in the RESS does need to be of redundant quality to ensure that overall availability is not compromised. These products are readily available, and are utilised widely.

6 Environmental and Safety Specification

6.1 Safety Specifications

The Radiant Node has been designed to fully meet the requirements of IEC 950 and EN 60950:2000.

6.2 Environmental Specifications

6.2.1 Outdoor Equipment Environmental Specification

Environmental Parameter		Unit	Value
a)	Low air temperature	^{o}C	-33
b)	High air temperature	^{o}C	45
c)	Low relative humidity	%	15
d)	High relative humidity	%	100
e)	Rain intensity (Survival)	mm/min	6
f)	Solar radiation	W/m^2	1120
g)	Movement of the surrounding air (Survival)	Mph	135
h)	Movement of the surrounding air (Operational)	Mph	95
i)	Conditions of condensation	none	Yes
j)	Conditions of precipitation	none	Yes

Table 7 - Outdoor Equipment Environmental Specification

6.2.2 Indoor Equipment Environmental Specification

Environmental Parameter		Unit	Value
a)	Low air temperature	^{o}C	1
b)	High air temperature	^{o}C	45
c)	Low relative humidity	%	5
d)	High relative humidity	%	90
e)	Solar radiation	W/m^2	700
f)	Movement of the surrounding air	m/s	5

Table 8 - Indoor Equipment Environmental Specification

7 Appendix A – Commonly Used Terms

7.1 Abbreviations

Term	Description
ATM	Asynchronous Transfer Mode
CPE	Customer Premises Equipment
DAMPS	Digital Advanced Mobile Phone System
DECT	Digital Enhanced Cordless Telecommunications
DEM	Digital Elevation Maps
xDSL	Digital Subscriber Line (variants)
FDD	Frequency Division Duplex
GSM	Global System for Mobile Communication
Ka Band 1	26 GHz Band
Ka Band 2	28 GHz Band
IDU	Indoor Unit
IP	Internet Protocol
ISDN	Integrated Services Digital Network
LEO	Low Earth Orbit (Satellite)
LoS	Line of Sight; an unobstructed geometrical line between two given points
MEM	Mesh Element Manager
MIB	Management Information Base
MIU	Management Interface Unit
MIP	Mesh Insertion Point
MMS	Mesh Management System
MPS	Mesh Planning System
MTBF	Mean Time Between Failures
ODU	Outdoor Unit
OLO	Other Licensed Operator
PoP	Point of Presence
PBX	Private Branch Exchange
PMP	Point-to-Multipoint
PPP	Point-to-Point Protocol
QoS	Quality of Service
RBWAN	Radiant Broadband Wireless Access Network
REP	Radiant Edge Processor

Term	Description
RESS	Radiant Edge Switch
SLA	Service Level Agreement
SNMP	Simple Network Management Protocol
STM-1 (or OC3)	The standard SDH 155Mbit/s service interface.
TDD	Time Division Duplex
TMN	Telecommunications Management Network
TNCP	Trunk Network Connection Point
TT	Trouble Ticket
UPS	Uninterruptible Power Supply
U Band	40GHz Band

7.2 Glossary of Terms

Term	Description
Adaptation	Adaptation is the process of changing the existing physical links of a Mesh segment and / or the existing traffic and management paths through a Mesh segment, to change from one fully operational Mesh configuration to another.
ATM Adaptation Layer	The layer that converts between the higher layer Customer services and the fixed size packets of the ATM network. This layer provides a multiplexing and de-multiplexing of Customer services onto the ATM network.
Craft Terminal	A hand held device used for site installation and maintenance that has a communications link to the MMS
Edge Services	Mesh services that are delivered edge-to-edge, such as shaping, policing and re-routing.
Element Manager	(or Element Management Subsystem) The subsystem that implements the Element Management Layer functions.
End Services	End-to-end services, typically user services such as IP, E1 & T1 etc. The ends are the user edge of the Mesh and the far side of the core network.
In-door Unit	This is the device that provides the user service adaptation. It connects to an Out-door unit at a Customer Node. It is considered to be one edge of the Mesh, and so implements "edge-functions" or "edge services".
Mesh Manager	(or Network Management Subsystem) The subsystem that implements the Network Element Management Layer functions.
Network Element	In the TMN model, these are the elements that are managed. In the Mesh
Mesh Insertion Point	An operator Node with an additional direct link (using any technology) to a TNCP. The main objective for the MIP is to start the spread of the Mesh.
Network Management Layer	The layer in the TMN model that is responsible for managing the entire network.
Node	A set of equipment in the Mesh, which is reachable by all other equipment without using a radio link, crossing a backhaul or a segment boundary. E.g. ODU and IDU
Out-door Unit	This is the node radio and switch used in building the Mesh. The Mesh is actually a Mesh of Out-door Units. Out-door Units are used in a variety of applications within the Mesh: as Seeds; at TNCPs; at MIPS and at Customer Nodes.
Permanent Virtual Circuit	A path across a number of ATM switches that is allocated as a function of management (set-up) rather than on a call basis. This path forms the basis of routing of cells within an ATM network.
Planning System / Tool	The combinations of functions and processes that perform the Network Planning.
Protection Switch (Protection Switching)	The switch that provides protection against network element failure.
Provisioning	The process of configuring all the relevant elements of a network to support a Customer service, or to remove support for a Customer service.

Term	Description
Radiant Edge Processor	The network edge peer to the Customers IDU. This is the functional point in the access network that implements the core-network side of the edge-edge services.
Radiant Edge-Switch System	The core network side protection switch for the access network
Seed network	The network comprising only Seeds and MIPs, which is all that exists before Customers are added, and subsequently forms the essential infrastructure of the growing Mesh.
Segment	A geographic area of network is divided into segments that are of manageable size. A network segment is the Mesh that is deployed in a planning segment including all the Mesh Nodes, all the core network interfaces and all the management network interfaces to Element Manager level. A single Element Manager manages a network segment.
Service Management Layer	The layer in the TMN model that is responsible for managing the telecommunication services.
Timeslot	The basic unit of time during which radio data transmissions occur between a pair of Nodes. The network uses time division multiplexing based on the division of time into repeated frames, each of which is further divided into timeslots.
Transit Node	Describes a role rather than a type of Node. A transit Node acts as a repeater for traffic originating and being forwarded elsewhere. It may also sink and/or source its own traffic.

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