APPENDIX A

IP Addresses

This appendix provides background information for readers unfamiliar with the considerations involved in assigning IP addresses to networks and hosts.

For additional information on IP addressing, see the following:

- *Internetworking with TCP/IP, Volume 1, Principles, Protocols, and Architecture*. Douglas E. Comer, 1991, Prentice-Hall, Inc. (ISBN 0-13-468505-9)
- *The Simple Book: An Introduction to Management of TCP/IP-based Internets*. Marshall T. Rose, 1991, Prentice-Hall, Inc. (ISBN 0-13-812611-9)
- *Interconnections: Bridges and Routers.* Radia Perlman, 1992, Addison-Wesley. (ISBN 0-201-56332-0)

LightStream 2020 Requirements

For each LS2020 node, you must provide from one to four IP addresses and the associated network masks, as follows:

- Primary NP address and mask (every LS2020 node)

  Nodes in an LS2020 network use their primary NP addresses to communicate network management traffic to one another.

Note All NP addresses within the same LS2020 network must have the same network number, and each LS2020 node must have a unique host ID.

- Subnet mask for the primary NP address

  The subnet mask specifies which portion of the IP address is the network number and which portion is the host ID. This mask is the same for all nodes on a given LS2020 network.

- Secondary NP address (only if a redundant NP is present in the LS2020 chassis)

  If an LS2020 node has a backup NP, it uses its primary and secondary NP addresses to pass network management traffic between the two NPs within the node. The primary NP address is used by whichever NP is active.

Note All NP addresses within the same LS2020 network must have the same network number, and each LS2020 node must have a unique host ID.

- NP Ethernet address and mask (only if an Ethernet LAN is connected to the NP[s])

  An Ethernet LAN may be attached to the NP for the communicating of management traffic between the node and a network management system (NMS). If an Ethernet LAN is connected to the NP, the NP's Ethernet IP address must be configured. If a backup NP is present, both NPs must be attached to the same Ethernet segment. The NP's Ethernet IP address is used by whichever NP is primary.

Note The Ethernet IP address has the network number for the attached Ethernet LAN (which must be different from the network number of the LS2020 network), plus a host number that is assigned by the network administrator of the Ethernet LAN.

- Subnet mask for the NP's Ethernet address

  The subnet mask for the NP's Ethernet address specifies which portion of the IP address is the network number and which portion is the host ID. This mask is the same for all nodes on the Ethernet LAN attached to the primary NP. You obtain the mask from the administrator of the Ethernet LAN.

- Default router (only if needed to reach the NMS)

  If an Ethernet LAN is attached to the primary NP, but the NMS is not directly connected to that LAN, a router on the Ethernet LAN can be configured as the default router. The default router on an LS2020 node provides a route from the node to the network management system (NMS). This IP address has the network number for the attached Ethernet LAN (which must be different from the network number of the LS2020 network), plus a host number that is assigned by the network administrator of the Ethernet LAN.

  If you plan to handle just one physical LS2020 network under your network ID number, and the network is a class C network, record 255.255.255.0 as the subnet mask. (The mask is 255.255.0.0 for a class B network with no subnetting, and 255.0.0.0 for a class A network with no subnetting.)

Note You can also manage the network through an Ethernet or FDDI LAN that is connected to an ordinary Ethernet or FDDI data port on the LS2020 node (that is, an Ethernet or FDDI access card port). The NMS must be directly attached to that Ethernet or FDDI LAN. In this case, do not configure the NP Ethernet address or default router address.

Additional information on management addresses can be found in the *LightStream 2020 Configuration Guide.*

What Are IP Addresses?

An IP address is a 32-bit identifier assigned to a host that uses the Internet Protocol. The IP address is represented by four octets (8-bit fields). In decimal form, an IP address consists of four fields separated by dots, where each field contains a value in the range 0 – 255. This is called *dotted decimal notation.*

Each host ID must be unique within a given network, and each network number must be unique within a given internet. Host IDs are assigned by the network administrator. The network number is assigned by the inter-network administrator. For a public network on the Internet, you must obtain a network number assigned by the Network Information Center (NIC).

An IP address consists of two parts. The first part of the address, called the network number, identifies a network on the internet; the remainder, called the host ID, identifies an individual host on that network. Historically, three classes of IP addresses have been defined:

- Class A—Only the first field identifies the network, and the number in the first field must be in the range 1 – 126 (127 is reserved for loopback). Class A networks are very large. Host numbers 0.0.0 and 255.255.255 are reserved, and one octet is reserved for other purposes, so there can be almost 17 million (2^{24}-2) hosts in a class A network. The 126 class A network numbers have been allocated.

  Example: 26.4.0.1, for host 4.0.1 on net number 26.

- Class B—The first two fields identify the network, and the number in the first field must be in the range 128 – 191. Class B networks are large. Host numbers 0.0 and 255.255 are reserved, so there can be up to 65,534 (2^{16}-2) hosts in a class B network. Most of the 16,382 class B addresses have been allocated.

  Example: 128.89.0.26, for host 0.26 on net 128.89.

- Class C—The first three fields identify the network, and the number in the first field must be in the range 192 – 223. (The range 224 – 255 is reserved for classes D and E, for experimental work.) Class C networks are relatively small. Host numbers 0 and 255 are reserved, so there can be up to 254 (2^{8}-2) hosts in a class C network. Most LANs are class C networks. There can be over 2 million class C networks in an internet.

  Example: 192.15.28.16, for host 16 on net 192.15.28.

Address Masks

An address mask determines which portion of an IP address identifies the network and which portion identifies the host. Like the IP address, the mask is represented by four octets. (An octet is an 8-bit binary number equivalent to a decimal number in the range 0 – 255). If a given bit of the mask is 1, the corresponding bit of the IP address is in the network portion of the address, and if a given bit of the mask is 0, the corresponding bit of the IP address is in the host portion.

The following table shows the mask 255.255.255.0 in both decimal and binary form, aligned with the class C address 192.15.28.16, also in both decimal and binary form:

Element		Network		Host
Mask	255	.255	.255	.0
	11111111	11111111	11111111	00000000
Address	192	.15	.28	.16
	11000000	00001111	00011100	00010000

If a field of the network address is entirely used for the network number, the corresponding field of the mask has the decimal value 255 (binary 11111111), and if an address field is entirely used for the host ID, the corresponding field of the mask has the decimal value 0 (see the following table).

Decimal Value in Field of Mask	Binary Value in Field of Mask	Function
255	11111111	Identify network number
0	00000000	Identify host ID

Accordingly, the address masks for the three network classes described above are as follows:

Address Class	Address Mask
A	255.0.0.0
B	255.255.0.0
C	255.255.255.0

Subnetting

The boundary between the network portion and the host portion of an IP address can be shifted by replacing the first zero in the host portion with a different number. By this means, more than one physically distinct network can be managed under a single class A, class B, or class C network number.

Subnet Masks

When a modified address mask is used to partition a network into subnets, it is called a *subnet mask.* The simplest subnet masks for the three classes of networks are as follows, where *n* is a number other than zero:

Address Class	Address Mask
A	255.*n*.0.0
B	255.255.*n*.0
C	255.255.255.*n*

(The other zeros in the mask for a class A or class B address can also be replaced by a different number, but, for simplicity, that possibility is ignored.)

Note Do not be confused by use of the term *subnetwork* for the individual networks that make up an internetwork. Each "subnetwork" in this latter sense has a different network number, but when a network is partitioned into subnets by a subnet mask, they all have the same network number.

The following is a simple example of subnetting partitions in a class B network.Set the third octet of the mask to 255, that is, use the address mask of a class C network. The following table shows the mask 255.255.255.0 in both decimal and binary form, aligned with the class B address 128.89.2.26, also in both decimal and binary.

Element	Network			Host
Mask	255	.255	.255	.0
	11111111	11111111	11111111	00000000
Address	128	.89	.2	.26
	10000000	01011001	00000010	00011010

Outside the network, packets are routed to net 128.89. It is only when packets reach a router that is directly connected to the network that routing software takes account of the subnet mask. The mask partitions net 128.89 into 254 subnets (numbers 0 and 255 are reserved), each supporting up to 254 hosts.

However, values other than 255 may be used, and, obviously, 255 cannot be used in the host field of a class C network. The mask value *n* that is substituted for 0 must be one of the decimal values shown in column 1 of the following table.

Column 1	Column 2	Column 3	Column 4
Decimal Value	Binary Value	Number of Subnets	Number of Host IDs
192	11000000	2	62
224	11100000	6	30
240	11110000	14	14
248	11111000	30	6
252	11111100	62	2

Note Any decimal value other than those shown in column 1 of the table above results in discontinuous strings of 1s and 0s, with undesirable consequences for software that interprets addresses subnetted under this mask.

Column 2 shows the values of *n* as binary numbers. These binary values are used in routing computations. If a given bit of the mask is 1, the corresponding bit of the IP address is part of the network ID. If a given bit of the mask is 0, the corresponding bit of the IP address is part of the host ID.

Column 3 indicates the number of subnets into which the mask partitions the network. If the first *n* mask bits are 1s, there are 2^n–2 subnets. (Two subnet numbers are reserved.)

Column 4 indicates the number of distinct host IDs that can be specified for each subnet using the remaining bits of this field. If the last *n* mask bits are 0s, there are $2^n–2$ hosts. (Two host IDs are reserved.)

Decimal value 254 (binary 11111110) is omitted from the table because it allows 0 hosts. Decimal value 0 (binary 00000000) and decimal value 128 (binary 10000000) are omitted because they allow 0 subnets.

Reserved Addresses

The reserved network numbers and host IDs that were subtracted from 2^n in columns 3 and 4 are as follows:

- The host number that is all 0s in binary is used to refer to the (sub)network itself. (The IP specification also reserves host 0.)

  For example, the address 192.15.28.0 refers to class C network 192.15.28.

- The network number that is all 0s in binary is used within a given network to refer to “this” network.

  For example, in a class C network with no subnetting, the address 0.0.0.16 refers to host 16 on “this” network. (Address 0.0.0.16 refers to host 0.16 in a class B network, or to host 0.0.16 in a class A network.)

- The host ID that is all 1s in binary is reserved as a broadcast address within a given (sub)network for all hosts on this (sub)network. (The IP specification also reserves a net or subnet number whose binary representation is all 1s.)

  For example, within the class C network 192.15.28, with no subnetting, the address 192.15.28.255 broadcasts to all hosts in this network.

- If the bits in the network portion are all 1s, the address is reserved.

  The range 224.0.0.0 through 255.255.255.254 is reserved for experimental use (IP address classes D and E), and 255.255.255.255 is the universal broadcast address.

Ranges of Host IDs

You know how to partition a network with a subnet mask, but you may not be able to determine which IP addresses fall in each of the subnets. The following example clarifies this.

Suppose you want to partition class C network 192.15.28 into five physical networks. Look in column 3 (Number of Subnets) of the last table in the Subnet Masks section. The closest approximation is to configure six subnets. To do this, enter 224 in the last field of the subnet mask. Thus, 255.255.255.224 is the subnet mask that you must specify to partition a class C network into six subnets.

The following table shows the mask 255.255.255.224 in both decimal and binary form, aligned with the class C address 192.15.28.16, also in both decimal and binary form.

Element	**Network**				**Host**
Mask	255	.255	.255	.224	
	11111111	11111111	11111111	111	00000
Address	192	.15	.28	.16	
	11000000	00001111	00011100	000	10000

By putting 224 in the last field of the mask, you tell the software to use the leftmost three bits of the last octet (the high-order bits) to differentiate subnets. In an 8-bit field, in binary notation, the three high-order bits naturally partition the range of numbers (and the range of possible IP addresses) into eight equal parts, corresponding to the eight binary numbers 000 through 111.

If you are not familiar with manipulating binary numbers and the example above is not clear to you, refer to the following table.

Decimal Range	**Binary Range**	**High Bits**
0 – 31	00000000 – 00011111	000
32 – 63	00100000 – 00111111	001
64 – 95	01000000 – 01011111	010
96 – 127	01100000 – 01111111	011
128 – 159	10000000 – 10011111	100
160 – 191	10100000 – 10111111	101
192 – 223	11000000 – 11011111	110
224 – 255	11100000 – 11111111	111

The three high-order bits of the IP address field thus partition the full range of 256 possible 8-bit numbers that can appear in the last octet of an IP address into eight groups of 32 addresses (256/8 = 32), as shown in the following table.

IP Address Ranges	Subnet	High Order Three Bits
192.15.28.0 – 192.15.28.31	0	000
192.15.28.32 – 192.15.28.63	1	001
192.15.28.64 – 192.15.28.95	2	010
192.15.28.96 – 192.15.28.127	3	011
192.15.28.128 – 192.15.28.159	4	100
192.15.28.160 – 192.15.28.191	5	101
192.15.28.192 – 192.15.28.223	6	110
192.15.28.224 – 192.15.28.255	7	111

However, addresses reserved for broadcast and for “this net” must be excluded. These exclusions are as follows:

- The range of numbers that have 000 or 111 in the network portion. This means that you must exclude the addresses shown for subnet 0 and subnet 7 in the table above.
- The range of numbers that have 00000 in the host portion: addresses with numbers 0, 32, 64, 96, 128, 160, 192, and 224 in the last field of the IP address. This means that you must exclude the first address in each of the address ranges noted in the table above.

Six Subnets in a Class B Network

Suppose you want to subnet class B network 128.89 into six subnets. Refer to Column 3 (Number of Subnets) in the last table in the section entitled “Subnet Masks.” You can see that the number to substitute for *n* is 224 if you want six subnets. The mask is 255.255.224.0 with six subnets. Recall that the mask is 255.255.0.0 with no subnetting. These two masks have the following binary representations:

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255.255.0.0      =    11111111.11111111.00000000.00000000

255.255.224.0    =    11111111.11111111.11100000.00000000
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With subnet mask 255.255.224.0, the first three bits of the third octet are included in the network identifier. You must divide 256 by the number of subnets to get the ranges of addresses for each subnet. The mask divides the range of numbers 0 – 255 that can appear in the third field of an IP address into eight ranges of 32 numbers: 0 – 31, 32 – 64, etc.

Since there are 11 bits in all for the host ID (eight in the last field, plus three in the third field), the mask 255.255.128.0 provides for 2046 ($2^{11}-2$) hosts in each of the eight subnets. The range of addresses for each subnet is shown in the following table.

IP Address Ranges	Subnet	High Order Three Bits
128.89.0.1 – 128.89.31.254	0	000
128.89.32.1 – 128.89.63.254	1	001
128.89.64.1 – 128.89.95.254	2	010
128.89.96.1 – 128.89.127.254	3	011
128.89.128.1 – 128.89.159.254	4	100
128.89.160.1 – 128.89.191.254	5	101
128.89.192.1 – 128.89.223.254	6	110
128.89.224.1 – 128.89.255.254	7	111

Subnet 0 is reserved because the addresses 128.89.0.1 – 128.89.31.254 have 000 as the high-order bits. Subnet 7 is reserved because the addresses 128.89.224.1 – 128.89.255.254 have 111 as the high-order bits.

The first address in each subnet address range is reserved for reference to the subnet as a whole because the last five bits of the address field are zeros. The last address in each subnet address range is reserved as a broadcast address for the subnet because the last five bits of the address field are ones. For example, in subnet 3, 128.89.96.0 is the subnetwork address and 128.89.127.255 is the broadcast address.