



Thunderbolt[™] Networking Bridging and Routing Instructional White Paper



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Table of Contents

1	Introduct	on	
	1.1	Equipment checklist for Thunderbolt™	Networking Communication4
	1.2	Basic vs. Multiple Thunderbolt [™] Netwo	rking Communication4
	1.2.1	Basic Communication	4
	1.2.2	Multiple Communication	5
2	Operation	Modes	6
	2.1.1	Bridging Mode	6
	2.1.1.1	Prerequisites	6
	2.1.1.2	Configuring Network Bridge on N	Vindows*6
	2.1.1.3	Optimizations for Windows* Bri	lging Performance9
	2.1.2	-	
	2.1.2.1	Overview	
	2.1.2.2	Enabling Routing on Windows* 7	/8.1
	2.1.2.3	Setting up Routing Configuration	(Example)13
3	Thundert	olt [™] networking communication with <i>F</i>	pple* computers16

1 Introduction

Thunderbolt[™] Networking allows for the connection of two or more computers through a Thunderbolt cable. Thunderbolt Networking uses the existing operating system's network sharing functionality to connect the systems as an Ethernet connection. It allows the computers to share resources between themselves as well as connect to devices within the connection chain to copy, transfer, share and/or print files and resources. The Thunderbolt Networking white paper is intended to provide an overview of how to set up network communication between two or more computers connected through Thunderbolt[™] Networking technology. It principally focuses on Windows* bridging and routing configurations. Thunderbolt[™] Networking Communication is also possible on Apple* computers running Mac OS and between computers running Mac OS and Windows OS, and is briefly covered in this document.

📝 Important:

This document is intended for users with a working knowledge in networking configuration and set-up of Windows 7/8.1, and/or Mac OS. Do not use this document if you do not feel comfortable working with these OS settings. This document uses screen captures and instruction from Windows 7, there may be slight differences in wording, commands and images when using Windows 8 and beyond.

1.1 Equipment checklist for Thunderbolt[™] Networking Communication

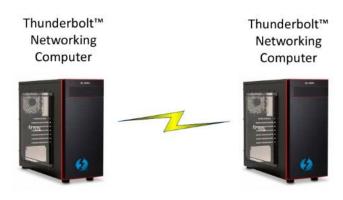
• Two or more Thunderbolt[™] 2 or above enabled computers with at least a single Thunderbolt[™] port. For multiple communication, computers in the middle of the bridging/routing chain must have a dual port controller.

• One or more Thunderbolt[™] cables.

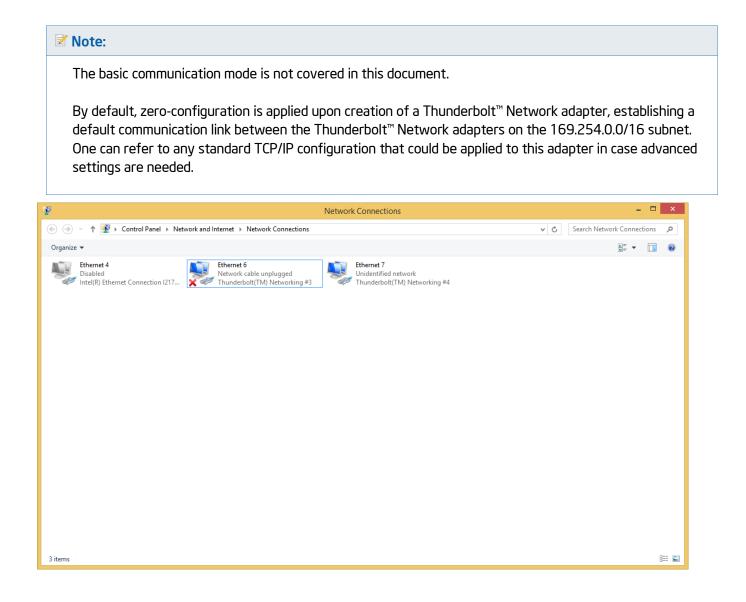
• Thunderbolt Software 2.5 or above installed on each computer. Thunderbolt Software version can be checked in the: Control Panel -> Programs -> Programs and Features. To update your Thunderbolt Software, contact your system integrator or original equipment manufacturer.

1.2 Basic vs. Multiple Thunderbolt[™] Networking Communication

1.2.1 Basic Communication



In the basic communication mode, two computers that support Thunderbolt[™] networking are connected directly via a Thunderbolt[™] cable. Once the standard Thunderbolt Software operations to authorize the access of the other computer have been completed, a new network (Ethernet) adapter will appear in the Windows Network Connections.



1.2.2 Multiple Communication



In this mode, multiple computers supporting Thunderbolt[™] Networking communicate through multiple Peer-to-Peer connections using Thunderbolt[™] 2 Dual Port hosts. In order to allow communication between different hosts in the Thunderbolt chain, network properties should be configured. We will cover two modes of operation: Bridging Mode and Routing mode.

Choosing between the two modes of operations mainly depends on user needs. Bridging is easier to set up run while the performance when using multiple computers will decrease with each computer added to the chain. Routing mode adds a certain level of complexity in configuration compared to bridging while generally achieving a higher point to point throughput, especially over longer computer chains.

📝 Note:

All computers in the Thunderbolt[™] chain need Thunderbolt[™] Software installed, regardless of their position in the chain. The Thunderbolt Networking should be first authorized in the Thunderbolt software before being able to set up the network configuration.

2 Operation Modes

2.1.1 Bridging Mode

2.1.1.1 Prerequisites

In this mode, dual port computers in the middle of the chain are configured as bridges. This means that all computers in the chain **must share the same subnet** to enable communication between them.

By default, if no IP configuration is applied to the Thunderbolt[™] Networking Adapter exposed by the Windows OS, an IP address is allocated by the zero-configuration networking methodology in the 169.254.0.0/16 subnet.

A static IP address can also be configured through the adapter properties menu:

• Right click the adapter icon in the **Network Connections** window and select Properties. Next double click on Internet Protocol Version 4 or Internet Protocol Version 6 item in the Ethernet Properties window Networking tab to setup the static IP address.

2.1.1.2 Configuring Network Bridge on Windows

Both adapters of a dual port computer must be added to Windows Network Bridge. In order to perform this operation:

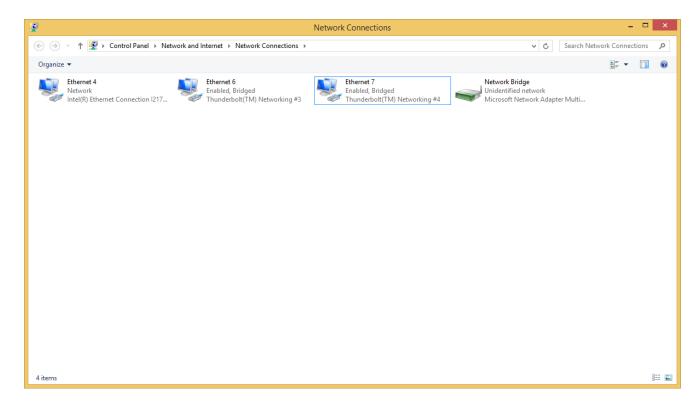
1. Right click on the first adapter and choose Add to Bridge from the menu.

😰 Network Connections – 🗖	×
🛞 🕘 👻 🕇 😰 > Control Panel > Network and Internet > Network Connections 🗸 🖒 Search Network Connections	,c
Organize 🔻 Disable this network device Diagnose this connection Rename this connection View status of this connection Change settings of this connection 🚆 💌 🗍	0
Ethernet 4 Network Intel(R) Ethernet Connection 121z Ethernet 6 Identifying Thunderb Oisable © Disable © Add to Bridge © Create Shortcut © Delete © Rename © Properties Ethernet 7 Identifying Thunderbolt(TM) Networking #4	
3 items 1 item selected	:== 🕥

2		Network (Connections		- 🗆	×
() → ↑ ↓ Control Panel → Net	work and Internet Network Connect	ions 🕨		∨ Ċ Se	arch Network Connections	Q,
Organize Disable this network device	Diagnose this connection Rena	me this connection	View status of this connection	Change settings of this connection	•= •	۲
Ethernet 4 Network Intel(R) Ethernet Connection I217	Ethernet 6 Enabled, Bridged Thunderbolt(TM) Networkir		themet 7 Inidentified network hunderbolt(TM) Networking #4	Network Bridge Unidentified network Microsoft Network Adapter M	- lulti	
4 items 1 item selected						::: 🗈

Upon addition, the Thunderbolt[™] networking adapter will appear as **Bridged** and, in addition, a new device will appear under the network connection called **Network Bridge**.

2. Repeat the **Add to Bridge** operation as described in step 1 for the second Thunderbolt[™] networking adapter. Upon addition, both adapters now show as **Bridged**.



Z Note:

At the time the Network Bridge is created, every Bridged Thunderbolt[™] networking adapter sees its IP address de-allocated and IP address allocation abilities stolen by Network Bridge. For configuration of the **Network Bridge** IP address, right click on it and then select **Properties**.

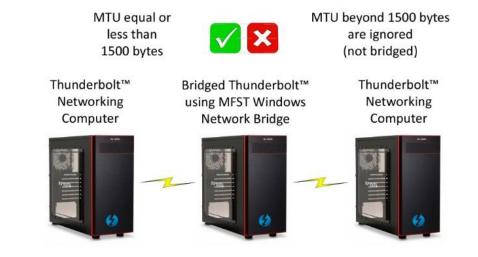
Once done, the bridge is set up and the bridging configuration completed. Computers should now be able to communicate through the bridge.

Hint: from a command prompt, one should be able to ping the other Thunderbolt[™] networking computer successfully.

C: > ping <ip address computer 2>

2.1.1.3 Optimizations for Windows Bridging Performance

By default the Thunderbolt Networking adapter is configured to use jumbo frames. For achieving the best communication performance results within the Windows Bridge, the MTU on the computers should be lowered to the bridge Ethernet MTU of 1500 Bytes. This can be done using WindowsNetshell command-line utility.



In order to perform this change the following needs to be executed from an elevated command prompt (Admin) on both computers at the 'edges' of the network.

netsh interface ipv4 set subinterface ``<name of the Thunderbolt^ adapter>" mtu=1500 store=persistent

Vote:

- This configuration should and can be applied on the computers at the edges of the network only. Windows
 Network Bridge on the intermediate dual port computers prevents any possible change on this parameter
 as it takes ownership on the adapters.
- In the command line "store=persistent" directive is used to make the change remain even after a restart of the computer.

2.1.2 Routing Mode

2.1.2.1 Overview

In this mode **one or more computers in the chain are configured as routers**, i.e. computers are routing traffic on the different subnets of the Thunderbolt network.

Routing service may be disabled on Windows OS and so it would need to be turned on first. The next section describes how to do this.

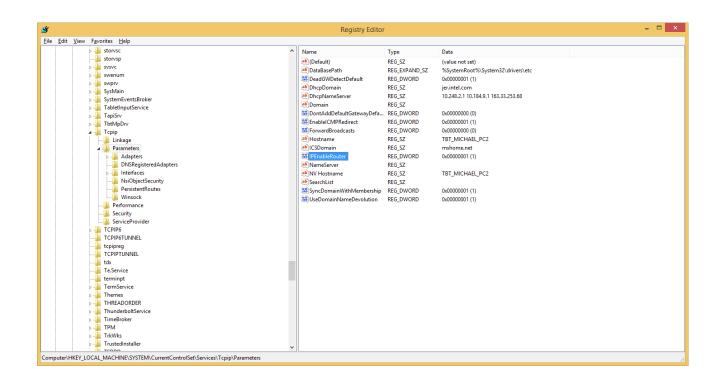
2.1.2.2 Enabling Routing on Windows 7/8.1

1. Configure the Windowsregistry tree for enabling routing: this can be done by executing the following command from an elevated Command prompt (Admin) that changes IPEnableRouter value to 1.

reg add "HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\Tcpip\Parameters"
/f /v "IPEnableRouter" /t REG_DWORD /d 0x1

Alternatively this can be carried out through the registry editor:

- o Call **regedit**.
- Browse to HKEY_LOCAL_MACHINE\SYSTEM\CurrentControlSet\Services\Tcpip\ Parameters
- Right click to IPEnableRouter.
- Choose **Modify** and input 1.



🗹 Important:

- Registry Editor is a tool intended for advanced users. Using Registry Editor incorrectly can cause serious
 problems that may require a re-installation of Windows or other issues. We recommend backing up the
 registry before making changes.
 - 2. Launch the service that performs the routing:

The service responsible for the routing is **Routing and Remote Access**, which may be disabled by default on Windows. In addition, the **Remote Access Auto Configuration Manager** service should be running as well.

From an elevated Command prompt (Admin), run the following command to launch the services GUI.

services.msc

a. Select **Remote Access Auto Connection Manager**. Right click on properties and choose startup type = Automatic. Click **Apply**. Go to **Services** status and click **Start**. Click **OK** to finish.

Services (Local)		
Remote Access Auto Connection Manager	Name	Description Status Startup Type Log On As
manager	Remote Access Auto Connection Manager	Creates a co Manual Local Syste
Start the service	Remote Access Connection Manager	Manages di Manual Local Syste
	Remote Desktop Configuration	Remote Des Manual Local Syste
Description:	Remote Desktop Services	Allows user Manual Network S r Allows the r Manual Local Svste
Creates a connection to a remote	Remote Desktop Services UserMode Port Redirector Remote Packet Capture Protocol v.0 (experimental)	
network whenever a program references a remote DNS or NetBIOS	Remote Procedure Call (RPC)	Allows to Ca. Vianual Local syste The RPCSS Running Automatic Network S
name or address.	Remote Procedure Call (RPC) Locator	In Windows Manual Network S
harre of outstept.	Remote Registry	Enabler com
	Routing and Remote Access	Offers routing Remote Access Auto Connection Manager Properties (
	RPC Endpoint Mapper	
	Secondary Logon	Resolves KP- Rig General Lig On Recovery Dependencies
	Secure Socket Tunneling Protocol Service	Provides su Service name: RasAuto
	Security Accounts Manager	The startup Ri Display name: Remote Access Auto Connection Manager
	Security Center	The WSCSV Ri
	Sensor Monitoring Service	Monitors va Rt Description: a program efferences a remote network whenever A a program efferences a remote DIS or Net BIOS
	Server	Supports film. R
	Shell Hardware Detection	Provides no R Path to executable:
	Smart Card	Manages ac C:\Windows\System32\avchost.exe +k netsvcs
	Smart Card Device Enumeration Service	Creates soft Statup type: Automatic
	Smart Card Removal Policy	Allows the s
	SNMP Trap	Receives tra (Automatic Version 2004)
	Software Protection	Chabled Inc. III
	Spot Ventier	Verifies pot Service status: Stopped
	Still Image Acquisition Events	Launches a. Stop Bause Besume
	Storage Service	Enforces gr You can specify the start parameters that apply when you start the service
	G Superfetch	Maintains a R Information of the adds particulated that apply much you adds the defector
	System Event Notification Service	Monitors sy- R Stat parameters:
	System Events Broker	CoordinateR
	C Task Scheduler	Enables a us Re
	C TCP/IP NetBIOS Helper	Provides su_ Rt OK Cancel Apply
	G Te.Service	R
	C Telephony	Provides Tel Manual Network S
	G Themes	Provides us Running Automatic Local Syste
	C Thread Ordering Server	Provides or Manual Local Service
	G Thunderbolt(TM) Service	Connects a Running Manual Local Syste
	Ca Time Broker	Coordinates Running Manual (Trig Local Service
	Touch Keyboard and Handwriting Panel Service	Enables Tou Manual (Trig Local Syste
	Q UPnP Device Host	Allows UPn Manual Local Service
	User Profile Service Output: Disk	This service Running Automatic Local Syste
	C Virtual Disk Volume Shadow Copy	Provides m Manual Local Syste Manages an Manual Local Syste
	WDK Driver Test Service	Manages an Manual Local Syste Allows a co Running Automatic Local Syste
	WDK Driver Test Service	Allows a co running Automatic Local syste Enables Wm Manual (Tria, Local Service
	Windows Audio	Enables WIRL Manual (Ing., Local service Local Service
Extended Standard	The second provide	

Check that the **Remote Access Auto Connection Manager** service is set to "Automatic" start up type and is running.

Services (Local)					
Remote Access Auto Connection	Name	Description	Status	Startup Type	Log On As
Manager	🤹 Remote Access Auto Connection Manager	Creates a co	Running	Automatic	Local Syste
Stop the service	🤹 Remote Access Connection Manager	Manages di	Running	Manual	Local Syste
Restart the service	🔍 Remote Desktop Configuration	Remote Des		Manual	Local Syste
	🌼 Remote Desktop Services	Allows user		Manual	Network S
Descriptions	🌼 Remote Desktop Services UserMode Port Redirector	Allows the r		Manual	Local Syste
Description: Creates a connection to a remote	🔍 Remote Packet Capture Protocol v.0 (experimental)	Allows to ca		Manual	Local Syste
network whenever a program	🌼 Remote Procedure Call (RPC)	The RPCSS	Running	Automatic	Network S
references a remote DNS or NetBIOS	🔍 Remote Procedure Call (RPC) Locator	In Windows		Manual	Network S
name or address.	🔍 Remote Registry	Enables rem		Disabled	Local Service
	🌼 Routing and Remote Access	Offers routi		Disabled	Local Syste
	🔍 RPC Endpoint Mapper	Resolves RP	Running	Automatic	Network S

b. Select **Routing and Remote Access**. Right click on **Properties** and choose startup type = Automatic. Click **Apply**. Go to **Services** status and click **Start**. Click **OK** to finish.

Check that the Routing and Remote Access service is set to "Automatic" start up type and is running.

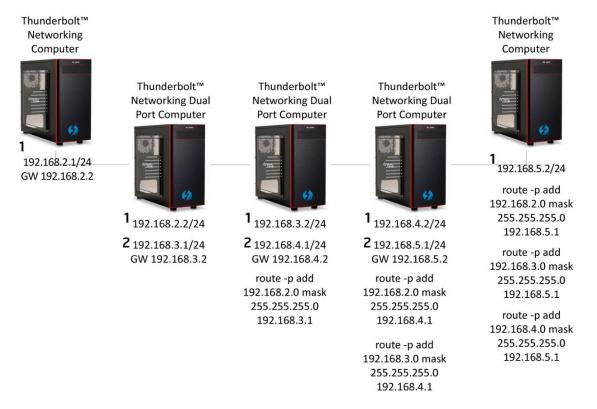
Routing and Remote Access	Name	Description	Status	Startup Type	Log On As
2	🤹 Routing and Remote Access	Offers routi	Running	Automatic	Local Syste
Stop the service	RPC Endpoint Mapper	Resolves RP	Running	Automatic	Network S
Pause the service Restart the service	Secondary Logon	Enables star	Running	Manual	Local Syste
	🔍 Secure Socket Tunneling Protocol Service	Provides su	Running	Manual	Local Service
- · · · ·	Security Accounts Manager	The startup	Running	Automatic	Local Syste
Description: Offers routing services to businesses	🔍 Security Center	The WSCSV	Running	Automatic (D	Local Service
in local area and wide area network	🌼 Sensor Monitoring Service	Monitors va	Running	Manual (Trig	Local Service
environments.	🔍 Server	Supports fil	Running	Automatic	Local Syste
	🌼 Shell Hardware Detection	Provides no	Running	Automatic	Local Syste
	Carried Card	NA		Discussion of the second se	1 1 0

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Choosing startup type "automatic" will allow the service to run each time your computer boots up. In case you want to manually control when routing is active, keep the startup type as "manual".

2.1.2.3 Setting up Routing Configuration (Example)

The illustration shows an example of a network that consists of 5 computers connected using Thunderbolt Networking. Setting up the network involves configuring a default gateway and the routing table on the network nodes.



In this configuration, the traffic is bi-directional and every computer is able to communicate with any other in the routed network.

- One direction of the bi-directional traffic (from left to right in the illustration) is achieved by the standard forwarding configuration defined by the default gateway. Defining a default gateway allows the traffic to be routed to the next hop automatically. Therefore every computer has a default gateway set to the closest computer connected through the daisy chain (apart for the last in the chain which does not need to forward further).
- The other direction of the bi-directional traffic (from right to left in the illustration) is achieved by adding static routing configurations to the Thunderbolt[™] computer in the network that it would like to communicate with (except to the closest hop subnet shared by the second adapter). In this case, Windows provides the "route" utility to roll out these configurations.

9	Network Connections	- 🗆 ×	- 🗆 🗙
(<) → ↑ (P → Control Panel → Network and Internet → Network C	onnections > v Ø Search Net	twork Connections 🔎	
Organize Disable this network device Diagnose this connection	Rename this connection View status of this connection Change settings of this connection		
Ethernet 4 Network Intel(R) Ethernet Connection 1217 Ethernet 6 Unidentified network Thunderbolt(TM) Net Ethernet 6 Properties			
Connect using:	You can get IP cettings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.		
This connection uses the following items:	O Obtain an IP address automatically Use the following IP address: IP address: IP address: IP 255.255.0 Default gateway: IP 2.168.2.2 O Obtain DNS server address automatically O Use the following DNS server addresses: Preferred DNS server: . Alternate DNS server: . Validate settings upon exit Advanced OK Cancel		
4 items 1 item selected		100	
Computer/HKEY_LOCAL_MACHINE\SYSTEM.CurrentControlSet\Services\Tcpip\P	v arameters		

In the above illustration the following steps are carried out for the configuration:

- The first computer (on the left) needs to be configured to forward packets to the next hop. Right click on the Thunderbolt[™] networking adapter. Click **Properties** and then select **Internet Protocol Version 4**. Click **Properties** again and configure **use the following IP address** with IP address = 192.168.2.1, Subnet mask = 255.255.255.0 and Default gateway = 192.168.2.2.
- 2. The second hop acts like a router. The first Thunderbolt[™] networking adapter is configured on the same subnet as the Thunderbolt[™] computer (192.168.2.x) to be able to communicate with it. Its address is 192.168.2.2 (without default gateway). The second Thunderbolt[™] networking adapter forwards the traffic to the next hop (defined as its default gateway in the adapter) and shares the same subnet as this one, i.e. 192.168.3.x. Its address is 192.168.3.1. Both adapters are configurable as defined in step 1.

Vote:

Defining more than one default gateway in the different Thunderbolt[™] networking or Ethernet adapters should be done with care to ensure that the traffic is forwarded to the desired interface. Additional rules may need to be created implicitly in the routing tables to support advanced scenarios.

3. In the illustration, some of the computers are set with a static routing table using Windowsroute utility. The reason is that by default all the traffic is routed to its default gateway or, alternatively, to the attached interface where its second adapter is attached, in case the traffic is intended to the second adapter's subnet. In the case another subnet is not indirectly reachable by the default gateway's path or directly by the second adapter, a static routing statement has to be added. For example, the second computer (from the left) needs to communicate with 192.168.2.x but all the traffic will be directed to its default gateway since it does not belong to any other direct subnets on it. Therefore a static routing statement has to be defined to indicate to the routing function (services) how to route the traffic to 192.168.3.2 interface onto the next hop (on the left in the illustration).

Therefore for this specific computer, from an elevated command prompt (Admin), the following routing statement should be executed:

route -p add 192.168.2.0 mask 255.255.255.0 192.168.3.1

🗹 Note:

The -p in the command makes it persistent (over restart). Do not use this switch if you want a temporary set-up.

The same kind of statement needs to be repeated at every computer that does not have direct or indirect access to certain subnets. For example, the 4th computer (from left) has to define static routing statements for reaching 192.168.2.x and 192.168.3.x subnets.

Vote:

The Windows "tracert" is a useful utility to ensure that the packets are going through the hops they are supposed to. Once the setup is complete, run it on different addresses to ensure that the right routing is defined.

3 Thunderbolt[™] Networking communication with Apple computers



Peer-to-Peer communication is supported on OS X Mavericks version 10.9.2 and beyond, which enables Ethernet network communication over Thunderbolt with any other Apple or Windows computer that deploys a Thunderbolt 2 port. If connecting to a Windows computer, Thunderbolt Software package 2.5 or above must be installed to use Thunderbolt Networking.

On Mac OS, the configuration for Thunderbolt[™] networking can be found under **System Preferences -> Network,** and is named **Thunderbolt Bridge**.

📝 Note:

To be able to communicate with another Windows computer through Thunderbolt[™] networking, the Apple computer should share the same subnet as the other computer.

In a multiple communication environment, Apple computers act as bridges. Therefore any computer in a networking chain that is Apple should have the same subnets as its connected peers.

For more information about Apple Thunderbolt solutions, refer to the Apple website at <u>https://www.apple.com</u> .