Ethernet Autonegotiation Best Practices

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Ethernet Autonegotiation Best Practices

This article discusses the advantages of using Ethernet autonegotiation when connecting Fast Ethernet (100 Mbps) and Gigabit Ethernet (1000Mbps) NICs to network switches, routers, and hubs. It emphasizes Sun's recommendation to leave Ethernet autonegotiation enabled (default) when connecting devices that are compliant with IEEE 802.3 standards.

Link failures, network delays, performance problems, and network troubleshooting difficulties can be alleviated and optimal link configuration is achieved with the correct implementation of Ethernet autonegotiation. Using autonegotiation is the IEEE 802.3 standard and customers are encouraged to follow the “intent” of IEEE 802.3u/z standards and implement autonegotiation in their Ethernet environments.

This article covers the following topics:

- *Autonegotiation Standards, Features, and Capabilities*
- *Interoperability Issues*
- *Loss of Functionality and Capabilities*
- *Alternative Methods*
- *Troubleshooting Difficulties*

The information in this article is for all levels of system and network administrators.

Autonegotiation Standards, Features, and Capabilities

Autonegotiation (AN) (Nway) technology was proposed to the IEEE in 1994 as a result of the need for a mechanism to accommodate multispeed network devices.

IEEE 802.3u standard clause 28 (for Fast Ethernet)

IEEE standard 802.3z Standard clause 37 (for Gigabit Ethernet)

With this technology, devices that share a link segment are automatically configured with the highest performance mode of interoperation. The autonegotiation activity exchanges information between two devices and is performed out-of-band using Fast Link Pulse (FLP) Burst (composed of 17 to 33 link pulses) to identify the highest physical-layer technology that can be used by both devices, such as 10BASE-T, 100BASE-TX, 100BASE-T4, 1000BASE-SX and 1000BASE-TX.

Autonegotiation on the link is exchanged when:

- Link is initially connected
- Device at either end of the link is powered up
- Device is reset or initialized
- Renegotiation request is made

The autonegotiation definition also provides a parallel detection function that allows the speed of the link to be established on legacy systems that do not have autonegotiation capabilities to ensure backward compatibility.

Other optional capabilities of autonegotiation are commonly used for added benefits such as Remote Fault Indication, Physical Management Interface, Asymmetric or Symmetric Pause capabilities, and automatic Media Detection Interface or (MDI) Media Detection Interface Crossover (MDIX) cable detection.

Autonegotiation link partner abilities are negotiated and use a priority resolution algorithm to establish the best mode of operation The following example is a normal priority scheme (from highest to lowest) for the autonegotiation link if a device has all the capabilities advertised and advertisement is enabled:

1. 1000 full duplex
2. 1000 half duplex
3. 100 full duplex
4. 100 half duplex
5. 10 full duplex

6. 10 half duplex

Autonegotiation is implemented at the Physical Link Layer as part of the Physical Coding Sublayer (PCS). Autonegotiation frames use a 16-bit Link Code Word (LCW) which can be seen using a network analyzer, as shown in following table.

```
 - - - - - - - - - - - - - - - - - - - - Frame 1 - - - - - - - - - - - - - - - - -
 Frame Status Source Address    Dest. Address      Size Rel. Time     Delta Time
    Abs. Time             Summary
     1 M [A]                                        10 0.000.000.000 0.000.000.
000 03/21/2002 11:34:21 AM DLC: Auto-Negotiation, size=10 (10-bit codes)
DLC:  Auto-Negotiation set 1 arrived at  11:34:21.2641; 10 (000A hex) 10-bit codes.
      DLC:  Configuration ordered set /C1/
      DLC:    Configuration Register (16 bits)
      DLC:      0....... ........ = No Next Page Request
      DLC:      .0...... ........ = No Page Acknowledgement
      DLC:      ..00.... ........÷1: = No Error, link OK
      DLC:      ....000. ........÷1: = Reserved
      DLC:      .......0 1.......÷1: = Symmetric PAUSE
      DLC:      ........ .0......÷1: = Half Duplex Disabled
      DLC:      ........ ..1..... = Full Duplex Enabled
      DLC:      ........ ...00000 = Reserved
      DLC:  Configuration ordered set /C2/
      DLC:    Configuration Register (16 bits)
      DLC:      0....... ........ = No Next Page Request
      DLC:      .0...... ........ = No Page Acknowledgement
      DLC:      ..00.... ........÷1: = No Error, link OK
      DLC:      ....000. ........÷1: = Reserved
      DLC:      .......0 1.......÷1: = Symmetric PAUSE
      DLC:      ........ .0......÷1: = Half Duplex Disabled
      DLC:      ........ ..1..... = Full Duplex Enabled
      DLC:      ........ ...00000 = Reserved
      DLC:
10-Bit           Hex     Decode     RD        Repeat
100111 1010      A0      D0.5       -
011000 1011      00      D0.0       +
110000 0101              K28.5      +
101010 1010      B5      D21.5      +      Configuration 1
100111 1010      A0      D0.5       -
011000 1011      00      D0.0       +
110000 0101              K28.5      +
101101 0101      42      D2.2       -      Configuration 2
011000 1010      A0      D0.5       +
100111 0100      00      D0.0       -      (Suppressed)
```

New technologies such as 1000BASE-T require autonegotiation.

The IEEE 802.3 standard default is to run with autonegotiation enabled. Technology improvements, and better interoperation of autonegotiation make it the preferred mode of operation, and is required on new technologies such as 1000BASE-T (802.3ab). While the standard on Fast Ethernet allows the ability to disable autonegotiation, it is neither required nor recommended for vendors to implement it.

The IEEE 802.3 standard states that you must support and test autonegotiation enabled to certify a product IEEE 802.3 compliant, and for multivendor interoperability (for example, testing at the UNH Interoperability Laboratory). There are no requirements in the standard to support locked down or forced configurations using autonegotiation disabled. As a result, there are no requirements for vendors to test multivendor interoperability between products with autonegotiation disabled.

The IEEE 802.3ab specification does not allow for forced mode 1000BASE-T with autonegotiation disabled running at 1000 Mbps. As a result, many switch vendors do not support forced mode. Although the transceiver used in the Sun™ Gigaswift Ethernet UTP adapter 1.0 is configurable for the 1000 Mbps forced mode and the `ce` driver allows this mode be aware that it does not work under certain circumstances.

Clause 40 (1000BASE-T), subclause 40.5.1 of 802.3 states:

> All 1000BASE-T PHYs shall provide support for Auto-Negotiation (Clause 28) and shall be capable of operating as MASTER or SLAVE. Auto-Negotiation is performed as part of the initial set-up of the link, and allows the PHYs at each end to advertise their capabilities (speed, PHY type, half or full duplex) and to automatically select the operating mode for communication on the link. Auto-negotiation signaling is used for the following two primary purposes for 1000BASE-T:
>
> a) To negotiate that the PHY is capable of supporting 1000BASE-T half duplex or full duplex transmission.
>
> b) To determine the MASTER-SLAVE relationship between the PHYs at each end of the link. 1000BASE-T MASTER PHY is c from a local source. The SLAVE PHY uses loop timing where the clock is recovered from the received data stream.

What this means is that although autonegotiation (Clauses 22 and 28) is optional for most variants of Ethernet and manual configuration (forced mode) is allowed, this is not the case for Gigabit copper (1000BASE-T). Per the IEEE 802.3u specification, it not possible to manually configure one link partner for 100 Mbps full duplex and still autonegotiate to full duplex with the other link partner. In all cases, both ends of the link must be set to the same value or the link may not connect or may result in duplex mismatch as shown in following tables.

For CSMA/CD compatible devices that use the eight-pin modular connector of ISO/IEC 8877: 1992 and that also encompass multiple operational modes, if a signaling method is used to automatically configure the preferred mode of operation, the autonegotiation function SHALL BE USED in compliance with Clause 28.

TABLE 1 FastEthernet Results

Switch Port Autonegotiation Advertisement Setting	NIC Autonegotiation Advertisement Setting	Switch Link	NIC Link
Enabled	Enabled	Status: Up Speed: 100Mbs Duplex: full	Status: Up Speed: 100Mbs Duplex: full
Disabled	Disabled	Status: Up Speed: 100Mbs Duplex: Undefined	Status: Up Speed: 100Mbs Duplex: Undefined
Enabled	Disabled Forced 100Mbs FDX	Status: Up Speed: 100Mbs Duplex: half	Status: Up Speed: 100Mbs Duplex: full
Disabled Forced 100Mbs full duplex	Enabled	Status: Up Speed: 100Mbs Duplex: full	Status: Up Speed: 100Mbs Duplex: half

TABLE 2 Gigabit Fiber Results

Switch Port Gigabit Autonegotiation Setting	NIC Gigabit Autonegotiation Setting	Switch Link	NIC Link
Enabled	Disabled	Status: Down	Status: Up
Disabled	Enabled	Status: Up	Status: Down
Enabled	Disabled	Status: Down	Status: Down
Disabled	Enabled	Status: Down	Status: Down

TABLE 3 Gigabit Copper Results

Switch Port Gigabit Autonegotiation Setting	NIC Gigabit Autonegotiation Setting	Switch Link	NIC Link
Enabled	Enabled	Status: Up	Status: Up
Disabled	Disabled	Status: Undefined	Status: Undefined
Enabled	Disabled	Status: Down	Status: Down
Disabled	Enabled	Status: Down	Status: Down

Locked-down port policies (forcing speed, duplex, and link capabilities with autonegotiation disabled) are outdated. Legacy and historical reasons for forced setup with autonegotiation disabled date back many years when the technology was new. Due to the maturity of the technology today, it no longer has the same issues of 5- to-10 years ago when 802.3u Fast Ethernet and 802.3z Gigabit Ethernet were new technology and many vendors had standard compliance issues. The UNH Interoperability Laboratory is used to ensure vendor compliance. These issues were resolved with NIC-driver patches, switch-firmware, and multiple generations of new product releases over many years. The notion of “autonegotiation is unreliable” can no longer be substantiated.

Not all network devices have the ability to force link capabilities for disabled autonegotiation policies. Some switches and drivers use autonegotiation (enabled) only and its usage is not optional. In the absence of autonegotiation (for example, using forced mode), link syncing between link partners may not occur and the link may not come up.

Even though the standard allows the ability to disable autonegotiation on Fast Ethernet 802.3u and Gigabit Ethernet 802.3z (fiber) technologies, it is neither required nor recommended. Do not disable autonegotiation between switches or NICs unless absolutely required, as physical layer problems may go undetected and result in spanning tree loops. Disabling autonegotiation should only be used as a troubleshooting aid or temporary workaround until the autonegotiation problem is resolved. The alternative to disabling autonegotiation is contacting the vendor for a software or hardware upgrade for IEEE 802.3 compliant Ethernet autonegotiation support.

Note – Forcing devices is problematic and adds administrative overhead. Legacy policies often create more administrative issues and network failures than they were intended to resolve.

When disabling autonegotiation, both ends of the link must match configuration values. This requirement makes it difficult to move physical connections or update devices with different capabilities. The administrative overhead of manually setting both link partners, verifying driver configurations, and checking Ethernet port statistics can be overwhelming on large Ethernet networks.

Enabling forced mode should be reserved only as a troubleshooting aid for link issues or as a temporary workaround until the autonegotiation problem is resolved (or with older pre-standard 100BASE-X switches that have a dated bug or do not comply with the standards). Upgrading software and hardware of network devices for IEEE 802.3u/z autonegotiation support is highly recommended.

Old policies from years past for locked-down forced autonegotiation disabled should be discouraged today.

Interoperability Issues

Duplex mismatch is one of the major issues when forcing speed and duplex on Ethernet devices. With the increasing number of Ethernet devices that have design restrictions or standards issues that require autonegotiation only and cannot be forced, interoperability is becoming a more common issue when autonegotiation is disabled. Not all devices support forced or disabled autonegotiation.

All Ethernet devices worldwide have a default setting of autonegotiation enabled because it is required by the IEEE 802.3 standard (802.3u, 802.3z, 802.3ab, and so on.) and most go through interoperability testing at shared facilities such as the UNH Interoperability Laboratory. The standard requires autonegotiation enabled as the default, while permitting ”forced” or autonegotiation disabled as “optional.”

The following Sun devices do not have ability to force speed and mode and use autonegotiation only:

- Sun Ray™ hardware appliances have no facility to support forced mode operation with disabled autonegotiation. If they are connected to a switch, the switch must be configured with autonegotiation enabled.
- Sun Fire™ 3800, 4800, 6800, 2900, Midrange Server system controller (SC) Ethernet ports used for platform administration have no facility to support forced mode operation. If the SC0, SC1 system controller Ethernet ports are connected to a switch, setting the switch ports to autonegotiation enabled is mandatory. If the SC Ethernets are connected to a forced switch port, the `eri` Ethernet ports of the SC drop to half duplex when connected to a forced 100Mbps full duplex (autonegotiation disabled) switch resulting in duplex mismatch. The resulting failures of duplex mismatch will lead to link errors (ierror, crc, runt, frag, length_errs, framing errs, late_collisions, and so on) on communication to and from the platform SCs. Critical Sun Fire platform administrative tasks like applying platform firmware flash-update patches may fail to upload and apply new firmware images.
- Sun Fire™ 12K/15K: High-End Server internal MAN networks used for communication between the SCs and the domains have no facility to support forced mode operation. The internal I1 MAN network between the SCs and the Domains (SC `eri2-19`, domain `eri0`) are half-duplex repeater-based platform-internal networks and cannot be changed. The I1 network operates at 100 Mbps half duplex and cannot be changed. This is because the hub on the I/O board functions as a repeater and cannot support full-duplex transfers. There is also an internal network between the two SCs consisting of two NICs (`eri0` and `hme1`) per system controller. This network is called the I2 network. It is entirely separate from the I1 network. The I2 network operates at 100 full duplex. Disabling autonegotiation and forcing 100 full-duplex system wide on networks affecting the Sun Fire 12/15K internally is not supported.

- Sun Fire E20K/E25K: High-End Server internal MAN networks used for communication between the SCs and the domains have no facility to support forced mode communication. The issue is nearly identical to the Sun Fire 12K/15K but the device names affected have changed in the newer system controller. The internal I1 MAN network between SCs and the Domains (SC eri4-21, domain eri0) are half-duplex repeater based platform-internal networks and cannot be changed. The I1 network operates at 100 Mbps half duplex and cannot be changed. This is because the hub on the I/O board functions as a repeater and cannot support full-duplex transfers. There is also an internal network between the two SCs consisting of two NICs (eri1 and eri2) per system controller. This network is called the I2 network. It is entirely separate from the I1 network. The I2 network operates at 100 full duplex. Disabling autonegotiation and forcing 100 full-duplex systemwide on networks affecting the Sun Fire E20K/25K internally is not supported.
- Network booting (performing a boot net or JumpStart™ operation with OpenBoot™ Prom (OBP) or prom-level Ethernet settings that are set at the factory to autonegotiation enabled). Since there is no Solaris™ operating system at network boot time, there are limited or often no means to configure or force autonegotiation settings.

  Device arguments for speed and duplex are optional and are not implemented in the FCode and OBP PROM versions of all Ethernet devices. Even though you can specify boot net options for newer cards as in this example for Gigaswift (`ce`) devices:

```
ok boot <path-to-device>:speed=100,duplex=full
```

  This does not address the issue with the boot and jumpstart image, because the default in the OS is `autonegotiation enabled` and `inetboot` does not honor arguments for device and network boot support without patches (see bugid No. 4670609).

  Additional modifications to the `driver.conf` files on the jumpstart server are required in this environment to implement forced speed or duplex.

  Also of note, older NICs, such as `hme` and `qfe`, do not have ability to select duplex at the OBP level. In summary, not implementing autonegotiation in a JumpStart environment adds extra administration and more chance of duplex mismatches at the various stages of the installation.
- Sun Blade™ 1600 switch internal ports: Forcing 1000BASE-T on an Uplink Port. Setting a port on the switch to 1000BASE-T with autonegotiation disabled is not possible because 1000BASE-T links have a master and slave end. Attempts to set autonegotiation disabled will leave the link unable to determine which end is the master or slave.

Loss of Functionality and Capabilities

Duplex mismatches are perhaps one of the most popular customer misconfigurations that leads to failures. Improperly forcing one link partner and not the other often results in duplex mismatch. A full-duplex link partner reports CRCs and framing errors. A half-duplex link partner reports excessive collisions and late collisions. Duplex mismatch may cause performance issues, dropped packets, corrupted network communication, dropped connections, and in Enterprise cases, network and application hangs.

Duplex mismatches result in the following:

- Packets dropped due to input errors result in retransmissions and delays
- Unexpected Cluster node failovers
- Unexpected IP Multipathing (IPMP) network interface failovers
- Unexpected Sun Trunking Ethernet link aggregation link failovers
- Switch ports with “port monitoring” or “port security” enabled may shut down ports with excessive errors
- Boot net install problems may fail or perform slowly.

Flow control Pause Frame configuration may be lost if the switch is configured for autonegotiation disabled. Certain switch vendors, for example, the Extreme Summit gigabit switch flow-control is implemented automatically in the autonegotiation enabled switch option. As long as autonegotiation is enabled, the switch properties to manage flow control are operational. Flow control is often needed to prevent Sun host NIC ierrors due to receive overflows (rx_overflow) especially when high bandwidth NICs are installed in slower SBus or PCI 33 MHz bus slots.

Data link layer issues are not detected if autonegotiation is disabled. Link quality issues cannot be detected and the system is unable to detect bad cables and unable to detect link failures. In addition, Media Dependent Interface (MDI) or Media Dependent Interface Crossover (MDIX) cable detection may not work.

Note – MDI and MDIX are a type of Ethernet port connection using twisted pair cabling. The MDI (for medium dependent interface) is the component of the media attachment unit (MAU) that provides the physical and electrical connection to the cabling medium. An MDIX (for MDI crossover) is a version of MDI that enables connection between like devices. MDI ports connect to MDIX ports using straight-through twisted pair cabling. Both MDI-to-MDI and MDIX-to-MDIX connections use crossover twisted pair cabling.

Alternative Methods

An alternative to forcing an interface or port with autonegotiation disabled is to keep autonegotiation enabled and only advertise the desired capability.

Example of switch configuration with autonegotiation enabled and 1000 full duplex is its only capability:

```
Console(config-if)#negotiation
Console(config-if)#capabilities 1000full
Console(config-if)#no capabilities 100full
Console(config-if)#no capabilities 10full
Console(config-if)#no capabilities 100half
Console(config-if)#no capabilities 10half
Console(config-if)#no capabilities 100half
Console(config-if)#no capabilities 10half
```

Example of driver.conf file (ce.conf) with autonegotiation enabled and 1000 full duplex is its only capability:

```
adv_autoneg_cap=1
adv_1000fdx_cap-1
adv_1000hdx_cap=0
adv_100fdx_cap=0
adv_100hdx_cap=0
adv_10fdx_cap=0
adv_10hdx_cap=0 ;
```

You can use the ndd utility to check the port negotiation capabilities on the Solaris driver (ce).

```
# ndd -set /dev/ce instance 0
# ndd -get /dev/ce adv_autoneg_cap
 1
```

and confirm that the link parnter (switch) has autonegotiation enabled as seen by ce.

```
# ndd -get /dev/ce lp_autoneg_cap
 1
```

The number 1 indicates autonegotiation is enabled, which should be the default.

Most swtiches have an ability to check that port negotiation is enabled.

```
Console> show port negotiation 4/1
Port   Link Negotiation
-----  ----------------
4/1    enabled
```

Troubleshooting Difficulties

Disabling autonegotiation can result in physical layer problems going undetected. Link partner, cable problems, and other Data Link layer issues are hidden from the administrator and manual examination of driver statistics is required.

- Unable to detect bad cables
- Unable to detect link failures
- Unable to check link partners capabilities
- Unable to move systems from one port to another or to another switch or router
- Unable to determine performance issues on higher layer applications
- Unable to implement Pause Frames (Flow Control)
- Difficulties in determining where system has forced setting configured (`/etc/system and driver.conf` using `ndd` in startup script

Link syncing between link partners may not happen and the link may not come up when autonegotiation is absent on 100BASE-T (UTP) copper.

Example of hme interface with duplex mismatch:

`hme0` has negotiated and failed back to HDX and experiencing crc babble and late_collisions.

```
# kstat -p hme:0::'/collisions|framing|crc|code_violations|tx_late_collisions/'

hme:0:hme0:code_violations      0
hme:0:hme0:collisions   16720
```

```
# kstat -p hme:0::'/collisions|framing|crc|code_violations|tx_late_collisions/'
hme:0:hme0:crc  0
hme:0:hme0:framing      0
hme:0:hme0:tx_late_collisions   5706
```

Example of hme interface with duplex mismatch:

hme1 is forced to FDX and experiencing framing, crc, and code_violation errors.

```
# kstat -p hme:1::'/collisions|framing|crc|code_violations|tx_late_collisions/'

hme:1:hme1:code_violations      147
hme:1:hme1:collisions   0
hme:1:hme1:crc  283
hme:1:hme1:framing      8
hme:1:hme1:tx_late_collisions   0
```

Example of switch port with duplex mismatch:

Port 11/22 has been forced to FDX (Full Duplex) but link partner is in HDX (half duplex), resulting in FCS (Frame Check Sequence) and runt errors.

```
Console> show port counters 11/22

Port  Align-Err  FCS-Err    Xmit-Err   Rcv-Err    UnderSize
----- ---------- ---------- ---------- ---------- ---------
11/22          0     572968          0          0         0
Port  Single-Col Multi-Coll Late-Coll  Excess-Col Carri-Sen Runts    Giants
----- ---------- ---------- ---------- ---------- --------- --------- ---------
11/22          0          0          0          0         0   9765322         0
```

Check that port negotiation is enabled on the switch:

```
Console> show port negotiation 4/1
Port   Link Negotiation
-----  ----------------
4/1    enabled
Console> show port negotiation 4/1
```

About the Authors

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Jim has designed, deployed, and analyzed networks over multiple technologies and protocols but most often focussed on Ethernet and IP protocols. He was the Technical Project Manager for a project with created a statewide network for the OHIO BWC (Bureau of Workers Compensation). Jim helped Sun launch its Sun Quad FastEthernet (QFE), Gigabit Ethernet, and SunSwitch products.

Steve Hodnett is a Staff Engineer in the Product Technical Support Technology Organization. He has provided high level support in the Network and Communications Group with Sun for past nine years in Burlington, MA. He has authored many knowledge articles on http://sunsolve.com focusing on Ethernet, IP protocols, and network applications. Prior to joining Sun, Steve worked for Agfa Compugraphic Corp as a Senior Technical Support Engineer and has over 15 years of experience in problem solving on a wide range of networking products and systems.

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- InfoDoc 43764

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