電腦網路 ch2.2-ch2.3

2.2 Physical background

2.2物理背景

Although the physical layer is a separate layer under the data-link layer in the OSI 7-layer model, they are usually tightly coupled. For example,

儘管物理層是OSI 7層模型中數據鏈路層下面的一個單獨層，但它們通常是緊密耦合的。例如，

the standards of Ethernet and 802.11 WLAN specify both layers. Therefore, before introducing the protocols in the data-link layer,

以太網和802.11 WLAN標準都指定了這兩個層。因此，在將協議引入數據鏈路層之前，

we first briefly introduce the technologies in the physical layer. The issues in the physical layer primarily include coding and modulation, which transforms data into some sort of signal for transmission,

我們首先簡要介紹一下物理層中的技術。物理層的問題主要包括編碼和調製，它將數據轉換為某種信號進行傳輸，

and medium, which physically carries the signal. Because the encoding depends on the transmission medium, we introduce the medium first and then the coding and modulation that accompany specific medium.

和介質，它們實際上承載信號。由於編碼取決於傳輸介質，因此我們首先介紹該介質，然後再介紹特定介質的編碼和調製。

2.2.1 Wired Medium and Coding/Modulation

2.2.1有線媒體和編碼/調製

Common wired medium include twisted pairs, coaxial cables and optical fibers.

常見的有線介質包括雙絞線，同軸電纜和光纖。

We describe their characteristics first and then the common coding and modulation methods for them.

我們先描述它們的特性，然後再描述它們的常見編碼和調製方法。

Twisted Pair

雙絞線

Twisted pairs consist of two conductors twisted together to prevent electromagnetic interference from the externals and crosstalk between the pairs.

雙絞線由兩個絞在一起的導體組成，以防止來自外部的電磁干擾和雙絞線之間的串擾。

A twisted pair cable may be shielded or not.

雙絞線電纜可能已屏蔽或未屏蔽。

A shielded cable is called STP (shielded twisted pairs) and an unshielded cable is called UTP (unshielded twisted pair).

屏蔽電纜稱為STP（屏蔽雙絞線），非屏蔽電纜稱為UTP（非屏蔽雙絞線）。

A STP can better prevent electromagnetic interference, but UTP is more common due to its lower cost and easy deployment. As the technology advances, UTP has been good enough for practical use.

STP可以更好地防止電磁干擾，但是UTP成本較低且易於部署，因此更為普遍。隨著技術的進步，UTP已經足以用於實際應用。

Twisted pairs are categorized according to the maximum frequency of signal in the specifications. Table 2.2 summarizes the common specifications in ANSI EIA/TIA Standard 568. The length limitation is usually 100 m in Ethernet, but it is

雙絞線根據規範中信號的最大頻率進行分類。表2.2總結了ANSI EIA / TIA標準568中的通用規範。在以太網中，長度限制通常為100 m，但在

not part of the EIA/TIA standard. The limitation depends on the layer-2 technology over the twisted pairs.

不屬於EIA / TIA標準的一部分。限制取決於雙絞線上的第2層技術。

Table 2.2 Specifications of common twisted pair cables.

Specifications	Description
Category 1/2	For traditional phone lines. Not specified in TIA/EIA.
Category 3	Transmission characteristics specified up to 16 MHz
Category 4	Transmission characteristics specified up to 20 MHz
Category 5(e)	Transmission characteristics specified up to 100 MHz
Category 6(a)	Transmission characteristics specified up to 250 MHz (Cat-6) and 500 MHz (Cat-6a)
Category 7	Transmission characteristics specified up to 600 MHz

To transmit with a higher bit rate,
要以更高的比特率傳輸，
one could either use a cable supporting higher frequency or design a more complicated coding scheme to encode more bits in the same period.
可以使用支持更高頻率的電纜，也可以設計更複雜的編碼方案來在同一周期內編碼更多位。
Although designing a complicated coding method to transmit data in low-frequency signal is possible,
儘管可以設計一種複雜的編碼方法以在低頻信號中傳輸數據，但
the circuitry cost is also high.
電路成本也很高。
As the cable cost is lowered,
隨著電纜成本的降低，
it is more economical to transmit over a better cable than to rely on complicated coding. For example,
通過更好的電纜傳輸比依賴複雜的編碼更為經濟。例如，
although Ethernet technology for transmitting 100 Mbps over Category 3/4 exists,
儘管存在通過類別3/4傳輸100 Mbps的以太網技術，
it is rarely found in practice. Almost all existing 100 Mb/s Ethernet is 100BASE-T,
在實踐中很少發現。現有的幾乎所有100 Mb / s以太網都是100BASE-T，
running over Category 5 cable.
在5類電纜上運行。

Coaxial Cable
同軸電纜

A coaxial cable consists of an inner conductor surrounded by an insulating layer,
同軸電纜由被絕緣層包圍的內部導體組成，
a conducting shield,
導電屏蔽
and a plastic jacket.
和一件塑料外套。
The cables are common for many applications,
電纜在許多應用中都很常見，
such as television networks and broadband Internet access using cable modems.
例如電視網絡和使用電纜調製解調器的寬帶Internet訪問。
It was also once popular medium for Ethernet,
它曾經也是以太網的流行媒介，
but has been mostly replaced by twisted pairs.
但大部分已被雙絞線取代。
Different types of coaxial cables have different the inner and outer parameters,
不同類型的同軸電纜具有不同的內部和外部參數，
which in turn affect the transmission characteristics such as impedance. So far,
進而影響傳輸特性，例如阻抗。至今，
the most popular type is RG-6,
最受歡迎的類型是RG-6
which has a diameter of 0.

直徑為0。

0403 inches,

0403英寸，

and can operate at around 3 GHz.

並可以在大約3 GHz的頻率下運行。

It is very popular for carrying signals for cable televisions and cable modems.

它在傳送有線電視和電纜調製解調器的信號時非常流行。

Optical Fiber

光纖

Optical fibers propagate the signal in light along the inner core of the cable. The light can be kept inside the core due to total internal reflection.

光纖沿著光纜的內芯傳播信號。由於全內反射，光可以保留在纖芯內部。

The light sources can be light emitting diode (LED) or laser.

光源可以是發光二極管（LED）或激光。

Optical fibers have the advantages over copper wires for communication applications because of their low attenuation and invulnerability to external interference. They are also harder to be tapped than copper cables.

光纖具有低衰減和抗外部干擾能力，因此在通信應用中具有優於銅線的優勢。它們也比銅電纜更難分接。

They are often used in high-speed and long-distance transmission,

它們通常用於高速和遠距離傳輸，

but they are mostly deployed as backbones rather than for personal use,

但它們大多部署為骨幹網，而不是供個人使用，

due to the high deployment cost.

由於部署成本高。

The two main categories of optical fibers are multi-mode fiber and single-mode fiber.

光纖的兩個主要類別是多模光纖和單模光纖。

The former has a larger core (typically larger than 50 μm).

前者的芯較大（通常大於50μm）。

Despite the lower cost of transmitter and receiver for interconnection,

儘管發射機和接收機的互連成本較低，

multi-mode fiber also introduces higher modal dispersion due to the diversity in propagation velocity of light signal.

由於光信號傳播速度的多樣性，多模光纖還引入了更高的模態色散。

The dispersion limits the bandwidth and the communication distance. The latter has a much narrower core (typically less than 10 μm).

色散限制了帶寬和通信距離。後者的芯要窄得多（通常小於10μm）。

It allows longer and higher-bandwidth transmission but at a higher cost.

它允許更長和更高帶寬的傳輸，但成本更高。

Coding and Modulation

編碼和調製

The transmission medium relies on coding (or line coding) or modulation for transmitting bits over the channel.

傳輸介質依靠編碼（或線路編碼）或調製來在通道上傳輸位。

Coding uses discrete-value discrete-time signal,

編碼使用離散值離散時間信號，

i.e. square wave,

即方波

characterized by only amplitude and timing to transmit 0's and 1's,

其特徵僅在於傳輸0和1的幅度和定時，

while modulation uses continuous-value,

雖然調製使用連續值，

continuous- or discrete-time,
連續或離散時間
signal characterized by amplitude,
以幅度為特徵的信號
frequency or phase to represent the bit stream.
代表比特流的頻率或相位。
Continuous-value signal can travel long distance,
連續值信號可以傳播很長的距離，
but the discrete-value square-wave signal sustains only for short distance. Coding simply uses specific square wave,
但是離散值方波信號僅維持短距離。編碼僅使用特定的方波，
or change of square wave,
或方波變化
to represent 0 and 1,
代表0和1
but modulation is more complicated in varying signal to convey data.
但是調製在改變信號以傳輸數據方面更加複雜。
Modulation itself can be analog,
調製本身可以是模擬的，
i.e. continuous-time,
即連續時間
or digital,
或數字，
i.e. discrete-time. Analog modulation conveys analog information such as TV or radio signal.
即離散時間。模擬調製傳達模擬信息，例如電視或無線電信號。
Because this book is dedicated to data communications,
由於這本書專門討論數據通信，
we introduce only digital modulation that carries the bit stream.
我們僅介紹承載比特流的數字調製。
Three major techniques are usually used in digital modulation: phase-shift keying (PSK),
數字調製通常使用三種主要技術：相移鍵控（PSK），
frequency-shift keying (FSK) and amplitude-shift keying (ASK),
頻移鍵控（FSK）和幅度移鍵控（ASK），
depending on which characteristic is varied to represent 1 and 0.
取決於哪個特性代表1和0。
PSK uses two different phases of reference signal to represent 1 and 0,
PSK使用參考信號的兩個不同相位來表示1和0，
respectively.
分別。
FSK uses two different frequencies,
FSK使用兩種不同的頻率，
and ASK uses two different amplitudes.
和ASK使用兩個不同的幅度。

More than one characteristic can be combined to pack more bits into the signal for higher transmission rate.
An example is quadrature amplitude modulation (QAM),
可以組合多個特徵以將更多的比特打包到信號中以提高傳輸速率。一個例子是正交幅度調製（QAM），
which varies both amplitude and phase to represent different bits.
它改變幅度和相位以代表不同的位。
For example,
例如，
two amplitudes and two phases can encode 2 bits,
兩個振幅和兩個相位可以編碼2位，
as there are totally four combinations in the characteristics.
因為特徵共有四個組合。
Each combination is called a symbol.

每個組合稱為符號。

In general,

一般來說，

a symbol of 2N combinations can transmit N bits at a time. If s symbols are transmitted per second,

2N個組合的符號一次可以傳輸N位。如果每秒傳輸s個符號，

then the baud rate is s per second,

那麼波特率是每秒s

and the data rate is sN bits per second.

數據速率為sN位/秒。

For example,

例如，

64-QAM has 64 combinations of different amplitudes and phases,

64-QAM具有64個振幅和相位不同的組合，

so it can transmit 6 bits per symbol.

因此每個符號可以傳輸6位。

However,

然而，

the combination is not free lunch.

組合不是免費的午餐。

First,

第一，

the circuitry for encoding and decoding becomes more complicated as the number of combinations increases.

隨著組合數量的增加，編碼和解碼電路變得更加複雜。

Second,

第二，

the variation between the combinations is minor as more combinations are packed in a symbol.

組合之間的差異很小，因為符號中會包含更多組合。

Therefore,

因此，

the signal is prone to errors and also requires robust error detection techniques for the transmission.

該信號容易出錯，並且還需要強大的錯誤檢測技術來進行傳輸。

Compared with the continuous signal transition in analog modulation,

與模擬調製中的連續信號轉換相比，

the transition in digital modulation happens only in discrete time. The simplest example is a high voltage can represent bit 1,

數字調製的過渡僅在離散時間內發生。最簡單的例子是高電壓可以代表位1，

and a low voltage can represent bit 0 on a copper cable. Thus,

低電壓可以表示銅電纜上的位0。從而，

a major problem of the transmission is synchronization.

傳輸的主要問題是同步。

The transmitter and the receiver may have minor variation in timing,

發射器和接收器的時序可能略有不同，

i.e. unsynchronized.

即不同步。

If a long series of identical bits are transmitted (i.e.,

如果傳輸了一連串相同的比特（即

the signal keeps the same),

信號保持不變），

the receiver may then sample the bits at incorrect time due to the timing variation.

然後，由於時序變化，接收機可能會在不正確的時間對這些位進行採樣。

Besides,

除了，

a long-distance transmission line may not be able transmit the direct-current (DC) component of a signal,

長途傳輸線可能無法傳輸信號的直流（DC）分量，

where the DC component means the average value of the signal when viewed from a frequency domain.

直流分量是指從頻域觀察時信號的平均值。

Thus,

從而，

the signal should have adequate variations.

信號應有足夠的變化。

Two solutions could guarantee the adequate variation of the signal.

兩種解決方案可以保證信號的適當變化。

First,

第一，

the signal can be self-clocking,

信號可以是自計時的

meaning the encoding of each bit must have a transition within the signal at the discrete time. Because a transition happens within each bit,

表示每個位的編碼在離散時間必須在信號內具有過渡。因為轉換發生在每一位，

the receiver can easily recover the clocking. Second,

接收器可以輕鬆恢復時鐘。第二，

the data bits to be transmitted can be transformed into longer blocks to guarantee the numbers of 0’s and 1’s are balanced.

可以將要傳輸的數據位轉換成更長的塊，以確保0和1的數量達到平衡。

The transformation is called block coding which is on top of line coding. For example,

這種轉換稱為塊編碼，它是在線編碼的基礎。例如，

the 4B/5B block coding transforms each block of four bits into five bits.

4B / 5B塊編碼將每個4位的塊轉換為5位。

Because the data space is expanded from 16 4-bit words to 32 5-bit words,

由於數據空間從16個4位字擴展到32個5位字，

16 extra words are available for additional purposes,

16個額外的單詞可用於其他目的，

such as control words that represent the start and end of a frame. Some words can be intentionally reserved for error detection.

例如代表一幀開始和結束的控製字。可以有意保留一些單詞以進行錯誤檢測。

Because no valid data words can be transformed into these reserved words,

由於無法將有效的數據字轉換為這些保留字，

if a reserved word is present in the receiver,

如果接收器中存在保留字，

a transmission error can be asserted.

可以斷言傳輸錯誤。

Moreover,

此外，

the 5-bit words from valid data words can be chosen to have balanced numbers of 1’s and 0’s.

可以選擇有效數據字中的5位字，使其平衡數為1和0。

Therefore,

因此，

the number of transitions in the line coding can be guaranteed.

可以保證行編碼中的轉換數量。

Besides 4B/5B coding,

除了4B / 5B編碼之外，

more complex block coding techniques,

更複雜的塊編碼技術

such as 8B/10B and 64B/66B,

例如8B / 10B和64B / 66B，

are also common for high-speed transmission.

在高速傳輸中也很常見。

These complex coding techniques can balance the numbers of bit 0 and bit 1 transmitted on the line by tallying where there are more 0’s or 1’s,

這些複雜的編碼技術可以通過計算更多的0或1來平衡線路上傳輸的位0和位1的數量，

and on-the-fly choosing the proper coding depending to which bit is more frequent.

然後根據哪個位更頻繁地選擇合適的編碼。

Since the 10-bit code-word has an imbalance of at most one additional one or zero,
由於10位代碼字的不平衡度最多為一個額外的1或0，
the tallying contains only one bit,
計數只包含一點點，
called the running disparity (RD).
稱為運行差異（RD）。
Each transmission of a code-word updates RD,
每次發送代碼字都會更新RD，
where RD+ denotes 1's are more than 0's,
RD +表示1大於0，
and RD- denotes the opposite. Moreover,
RD-表示相反的意思。此外，
the wide code space also allows a degree of error detection in the physical layer.
寬的代碼空間還允許在物理層中進行一定程度的錯誤檢測。
If a receiver receives an illegal code,
如果接收者收到非法代碼，
it can judge that a transmission error occurs,
它可以判斷發生傳輸錯誤，
and drop the frame.
放下框架。

Standard Coding and Modulation Techniques
標準編碼和調製技術

Table 2.3 summarizes common coding and modulation techniques for three wired media, as well as the standards that use the techniques. We introduce each technique as follows.
表2.3總結了三種有線媒體的常見編碼和調製技術，以及使用這些技術的標準。我們介紹以下每種技術。

Table 2.3 Coding/modulation techniques used in standard links.

twisted pair	coaxial cable	optical fiber
MLT-3 (100BASE-TX) OFDM (ADSL)	Manchester (10BASE-T) QAM (DOCSIS)	NRZ(1000BASE-X)

Quadrature Amplitude Modulation (QAM): The QAM modulation varies both amplitude and phase to represent different bits.
正交幅度調製（QAM）：QAM調製同時改變幅度和相位以表示不同的位。
The two phases in the signal are separated by 90 degrees,
信號中的兩個相位相隔90度，
thus it is named quadrature. The cable modem standard,
因此，它被稱為正交。電纜調製解調器標準，
DOCSIS,
DOCSIS，
follows the QAM scheme in cable television distribution to transmit data for compatibility.
遵循有線電視分配中的QAM方案來傳輸數據以實現兼容性。
64-QAM and 256-QAM are the mandated schemes for digital cable in the US.
64-QAM和256-QAM是美國數字電纜的強制性方案。

Orthogonal Frequency-Division Multiplexing (OFDM): The modulation can be used in both wired and wireless applications.
正交頻分複用（OFDM）：該調製可用於有線和無線應用。

The modulation uses a number of orthogonal sub-carrier signals.
調製使用許多正交子載波信號。
Because each sub-carrier is orthogonal to each other,
由於每個子載波彼此正交，
crosstalk between them is eliminated and the guard band between two contiguous sub-carrier signals is unnecessary.
消除了它們之間的串擾，並且不需要兩個連續子載波信號之間的保護帶。
The sub-carrier signal is modulated with ordinary method,
副載波信號採用普通方法調製，
say QAM,
說QAM，
at a low rate. New standards of ADSL use OFDM because the phone line is vulnerable to external interference,
低速率。 ADSL的新標準使用OFDM，因為電話線容易受到外部干擾，
and OFDM is robust to noise in high-speed transmission.
OFDM對高速傳輸中的噪聲具有魯棒性。

Non-Return-to-Zero (NRZ): The coding is very simple. One physical level (voltage,
不歸零（NRZ）：編碼非常簡單。一個物理水平（電壓，
current,
當前，
etc.
等等
) stands for 1,
）代表1，
and the other stands for 0.
另一個代表0。
Although NRZ is very simple,
儘管NRZ非常簡單，
1000BASE-X Ethernet still runs NRZ because its block coding 8B/10B has provided sufficient capability for high-speed transmission,
1000BASE-X以太網仍然運行NRZ，因為其塊編碼8B / 10B為高速傳輸提供了足夠的能力，
and using NRZ as the line coding scheme is cheap in design.
並且使用NRZ作為線路編碼方案在設計上便宜。

Non-Return-to-Zero,
不歸零，
Inverted (NRZI): A transition in discrete time represents 1,
反相（NRZI）：離散時間的躍遷表示1，
and no transition represents 0.
並且沒有過渡表示0。
Manchester: This coding can guarantee signal transition in each data bit for self-clocking. However,
曼徹斯特：此編碼可以保證每個數據位中的信號跳變，以實現自計時。然而，
the signal frequency is also doubled.
信號頻率也加倍。
Thus,
從而，
Manchester coding demands doubled bandwidth to achieve the same data rate as NRZ.
曼徹斯特編碼需要兩倍的帶寬才能達到與NRZ相同的數據速率。
10BASE-T uses Manchester for its self-clocking capability to synchronize the transmission between two ends.
10BASE-T使用曼徹斯特的自計時功能來同步兩端之間的傳輸。
Because it demands more bandwidth,

由於需要更多的帶寬，

it is not adopted for higher transmission rate,

它不被用於更高的傳輸速率，

such as 100 Mb/s Ethernet.

例如100 Mb / s以太網。

MLT-3: The coding cycles through three levels to transmit 1: +1,

MLT-3：編碼通過三個級別循環以傳輸1：+1，

0,

0，

-1 and 0,

-1和0，

where +1 denotes a positive physical level and -1 denotes a negative one,

其中+1表示正的物理水平，而-1表示負的物理水平，

and keeps at 0 when transmitting 0.

並在傳輸0時保持為0。

Because MLT-3 needs four transitions to complete a full cycle,

由於MLT-3需要進行四個轉換才能完成一個完整週期，

the data rate is reduced to only one-fourth of the baud rate. This feature makes MLT-3 suitable for transmission over copper cables at a lower frequency.

數據速率僅降低到波特率的四分之一。此功能使MLT-3適合在較低頻率下通過銅纜傳輸。

100BASE-TX adopts MLT-3 because of its advantage of low fundamental frequency,

100BASE-TX由於其低基頻的優勢而採用MLT-3，

which is 31.25 MHz (100 Mbits becomes 125 Mbits,

這是31.25 MHz（100 Mbit變為125 Mbit，

which is also 125 Mbaud/s,

也是125 Mbaud / s，

after 4B/5B block coding. The fundamental frequency is only one-fourth of the baud rate,

經過4B / 5B塊編碼。基本頻率僅為波特率的四分之一，

so at least 4 bits are required to generate a complete cycle. Hence the highest frequency is 125/4 = 31.25 MHz.

因此至少需要4位才能生成一個完整的周期。因此，最高頻率為125/4 = 31.25 MHz。

) Therefore,

）因此，

the signal can be easily carried on a CAT-5 cable. Modulation and coding should be optimally tuned to adapt to the characteristics of a given medium type. Complicated modulation or line coding techniques generally help to transmit at high data rate even in a low-bandwidth channel.

信號可以輕鬆地通過CAT-5電纜傳輸。調製和編碼應進行最佳調整，以適應給定介質類型的特徵。複雜的調製或線路編碼技術通常甚至在低帶寬信道中也有助於以高數據速率進行傳輸。

For example,

例如，

transmission at gigabit per second even on barbed wires has been demonstrated in short distance with a complicated coding technique. However,

在短距離內已經通過複雜的編碼技術證明了即使在鐵絲網上，千兆位每秒的傳輸速度也得到了證明。然而，

as mentioned previously,

如前所述，

complicated coding also leads to high cost in the circuitry of the transmitter and receiver.

複雜的編碼還導致發射器和接收器的電路成本高昂。

Therefore,

因此，

besides the factors in technology,

除了技術因素，

cost is also a tradeoff that should be considered.

成本也是應該考慮的折衷方案。

2.2.2 Wireless Medium and Coding/Modulation The most obvious advantage of wireless networking over wired networking is mobility.

2.2.2無線介質和編碼/調製無線網絡相對於有線網絡的最明顯優勢是移動性。

Unlike wired connection that uses a cable for transmission,

與使用電纜進行傳輸的有線連接不同，

wireless connection uses the wireless spectrum.

無線連接使用無線頻譜。

As discussed in Subsection 1.1.1,

如第1.1.1節所述，

most wireless systems use the microwave spectrum (108~1011 Hz),

大多數無線系統使用微波頻譜（108～1011 Hz），

especially 800MHz to 2 GHz,

特別是800MHz至2 GHz，

to balance between omni-directionality and high bit rate. Higher spectrum can offer higher bit rate but then become more directional.

在全方向性和高比特率之間取得平衡。較高的頻譜可以提供較高的比特率，但隨後將具有更大的方向性。

Microwave transmission needs available bands in that spectrum allocated from regulatory authorities.

微波傳輸需要從監管機構分配的頻譜中的可用頻段。

Fortunately,

幸好，

the bands named ISM bands (e.g.,

名為ISM頻段的頻段（例如，

2.4 GHz for wireless LAN),

無線局域網的2.4 GHz），

meaning industrial,

意思是工業

scientific and medical are available without a license. A common example that uses the ISM bands is the microwave oven operating in the 2.4 GHz band.

未經許可即可獲得科學和醫學資料。使用ISM頻段的一個常見示例是在2.4 GHz頻段運行的微波爐。

Besides microwave oven,

除了微波爐

cordless phones,

無繩電話

wireless LAN,

無線網絡，

as well as many wireless devices also operate in the bands,

以及許多無線設備也在這些頻段中運行，

as the bands are license free. Since many devices share the ISM bands,

因為樂隊是免費的。由於許多設備共享ISM頻段，

techniques to avoid interference among these devices are needed.

需要避免這些設備之間干擾的技術。

Spread spectrum,

擴頻

which diffuses the signal power over a range of spectrum,

它將信號功率擴散到整個頻譜範圍內，

is the right technology used in WLAN to avoid interference. Because a signal spread over a wider spectrum may not be affected by a narrow-band noise,

是在WLAN中使用以避免干擾的正確技術。由於擴頻後的信號可能不會受到窄帶噪聲的影響，

the receiver thus has a better chance to recover the spread signal clearly.

因此，接收機有更好的機會清楚地恢復擴頻信號。

Three common spread spectrum techniques are summarized below.

下面總結了三種常見的擴頻技術。

Frequency Hopping (FH)

跳頻（FH）

Frequency hopping jumps from one frequency slot to another in a random,

跳頻隨機地從一個頻率段跳到另一個頻率段，

but predictable pattern.

但可預測的模式。

The hopping is rapid.

跳躍是迅速的。

For example,

例如，

in IEEE 802.11 wireless LAN,

在IEEE 802.11無線局域網中

the time slot of each frequency is only 50 μs.

每個頻率的時隙只有50μs。

Predictability is important as the receiver needs to know the pattern used by the transmitter to correctly receive the signal.

可預測性很重要，因為接收器需要知道發射器用來正確接收信號的模式。

Because the frequency in which the signal appears keep changing,

由於信號出現的頻率不斷變化，

the signal interfered by noises in a certain band is only transient.

在某個頻帶內受噪聲干擾的信號只是瞬態的。

Synchronization in timing between the transmitter and the receiver is critical because the receiver must switch the frequency slot at exactly the same time as the transmitter does.

發送器和接收器之間的時序同步至關重要，因為接收器必須在與發送器完全相同的時間切換頻率時隙。

When two frequency hopping pairs are present,

如果有兩個跳頻對，

each is assigned a different hopping pattern.

每個都分配有不同的跳躍模式。

Therefore,

因此，

they can minimize the interference between each other,

它們可以最大程度地減少彼此之間的干擾，

as long as the frequency slot is different in a given time slot.

只要頻率時隙在給定的時隙中不同即可。

A device can synchronize with others by receiving a special beacon frame that carries the related parameters.

設備可以通過接收帶有相關參數的特殊信標幀來與其他設備進行同步。

Direct Sequence (DS)

直接序列（DS）

Direct sequence spreads the signal power over a wide spectrum with a mathematical transform,

直接序列通過數學變換將信號功率擴展到很寬的頻譜，

and so the noise in a certain band can hardly disrupt the entire signal.

因此，某個頻帶中的噪聲幾乎不會破壞整個信號。

The spreading process is performed by encoding a data bit into a sequence of bits,

通過將數據位編碼為一系列位來執行擴展過程，

called chips.

叫做籌碼。

For example,

例如，

bit 1 is encoded into 11001011110 and bit 0 is encoded into 00110100001. The number of chips to represent a bit is called the spreading ratio.

位1編碼為11001011110，位0編碼為00110100001。表示位的碼片數稱為擴頻比。

The chips are generated in a stream from pseudo-random numbers at a much higher rate,

這些碼片是由偽隨機數以更高的速率從流中生成的，

and so the bit sequence of chips keeps changing as the data is transmitted.

因此，芯片的位序列隨著數據的傳輸而不斷變化。

Choosing the spreading ratio is a tradeoff.

選擇傳播比率是一個折衷。

High spreading ratio can better recover the data bits,

高擴頻比可以更好地恢復數據位，

but it also needs high operating frequency and demands more bandwidth.

但它也需要較高的工作頻率，並需要更多的帶寬。

Orthogonal Frequency Division Multiplexing (OFDM)
正交頻分複用（OFDM）
As described for the wired links,
如有線鏈接所述，
the available channel is divided into several small ones orthogonal to each other,
可用信道被分成幾個相互正交的小信道，
and the data is also encoded in each sub-channel,
並且數據也在每個子通道中進行了編碼
or sub-carrier,
或副載波，
in parallel.
在平行下。
This technique is also used for wired transmission,
此技術也用於有線傳輸，
such as ADSL as seen in the previous subsection.
如上一小節所示的ADSL。
Traditional frequency division multiplexing has lower channel utilization due to the guard band that separates the sub-carriers.
由於分開子載波的保護頻帶，傳統的頻分複用具有較低的信道利用率。
The sub-carriers in OFDM can overlap because they are orthogonal in a mathematical sense. Table 2.4 summarizes the relations of standards and the spread spectrum techniques.
OFDM中的子載波可以重疊，因為它們在數學意義上是正交的。表2.4總結了標準與擴頻技術之間的關係。
Frequency hopping and direct sequence are sufficient for low-speed transmission,
跳頻和直接序列足以用於低速傳輸，
but you can find OFDM is adopted to transmit at high speed for its capability to cope with severe channel condition,
但是您會發現OFDM能夠應付惡劣的信道條件，因此可以高速傳輸，
say attenuation in high frequency,
說高頻衰減
without complex modulation design.
沒有復雜的調製設計。

Table 2.4 Spread spectrum techniques used in standard wireless links.

Frequency hopping	802.11, Bluetooth
Direct sequence	802.11, 802.11b
OFDM	802.11a, 802.11g, 802.11n (with MIMO), WiMAX

2.3 Point-to-point protocol
2.3點對點協議
This section focuses on the Point-to-Point Protocol (PPP),
本節重點介紹點對點協議（PPP），
a widely used protocol in traditional dial-up lines or ADSL to the Internet.
是傳統撥號線路或ADSL到Internet的一種廣泛使用的協議。
PPP was derived from an old,
PPP源自舊的
but widely used protocol,
但被廣泛使用的協議
High-level Data Link Control (HDLC).

高級數據鏈接控制（HDLC）。

Within its operations are two protocols,

在其操作中，有兩個協議，

Link Control Protocol (LCP),

鏈路控制協議（LCP），

and Network Control Protocol (NCP).

和網絡控制協議（NCP）。

As Ethernet extends to home and organizations,

隨著以太網擴展到家庭和組織，

with a bridge device such as ADSL modem,

使用橋接設備（例如ADSL調製解調器）

connected to the Internet Service Provider (ISP),

連接到Internet服務提供商（ISP），

there is a requirement of PPP over Ethernet (PPPoE).

以太網上的PPP（PPPoE）的要求。

Figure 2.5 shows the relationship between these components.

圖2.5顯示了這些組件之間的關係。

Figure 2.5 Relationship of PPP-related protocols.

2.3.1 High-level Data Link Control (HDLC)

2.3.1高級數據鏈路控制（HDLC）

Derived from an early protocol,

源自早期協議，

Synchronous Data Link Control protocol (SDLC) by IBM,

IBM的同步數據鏈路控制協議（SDLC），

the HDLC protocol is an ISO standard and the basis of many other data-link protocols.

HDLC協議是ISO標準，也是許多其他數據鏈路協議的基礎。

For example,

例如，

the PPP uses HDLC-like framing. IEEE 802.2 Logical Link Control (LLC) is a modification of HDLC.

PPP使用類似HDLC的幀。 IEEE 802.2邏輯鏈路控制（LLC）是對HDLC的修改。

CCITT (renamed ITU in 1993) modified HDLC as part of the X.

CCITT（於1993年更名為ITU）修改了HDLC作為X的一部分。

25 standard,

25標準

called Link Access Procedure,

稱為鏈接訪問程序

Balanced (LAP-B).

平衡（LAP-B）。

In all variations,

在所有變化中，

HDLC supports point-to-point and point-to-multipoint link,

HDLC支持點對點和點對多點鏈接，

and half-duplex and full-duplex link.

半雙工和全雙工鏈接。

We next take a look of the HDLC operation.

接下來，我們看一下HDLC的操作。

HDLC Operation: Medium Access Control

HDLC操作：介質訪問控制

In HDLC, stations are either primary or secondary stations. HDLC supports the following three transfer modes. Note that it is the way how stations are controlled to access the medium.

在HDLC中，站是主站或輔助站。 HDLC支持以下三種傳輸模式。請注意，這是控制站訪問介質的方式。

Normal response mode (NRM): The secondary station can only passively transmit data in response to the primary's poll. The response may have one or more frames.

普通響應模式（NRM）：輔助站點只能響應主站點的輪詢而被動發送數據。該響應可以具有一個或多個幀。

In a point-to-multipoint scenario, secondary stations must communicate through the primary station.

在點對多點方案中，輔助站點必須通過主站點進行通信。

Asynchronous response mode (ARM): The secondary station can initiate the data transfer without the primary's poll, but the primary is still responsible for controlling the connection.

異步響應模式（ARM）：輔助站點可以在沒有主站點輪詢的情況下啟動數據傳輸，但是主站點仍然負責控制連接。

Asynchronous balanced mode (ABM): Both parties in communication can play the role of the primary and the secondary. It means both stations have equal status.

異步平衡模式（ABM）：通信雙方可以扮演主要和次要角色。這意味著兩個站的狀態相同。

This type of station is called a combined station.

這種類型的站稱為組合站。

NRM is often used in a point-to-multipoint links, such as those between a computer and its terminals. ARM is rarely used. It has advantages for point-to-point link, but ABM is even better. ABM has less overhead such as the

NRM通常用於點對多點鏈接中，例如計算機與其終端之間的鏈接。很少使用ARM。它具有點對點鏈接的優點，但ABM更好。 ABM的開銷較小，例如

primary's poll,

初級民意測驗

and both parties can have control over the link. It is suitable for a point-to-point link.

雙方都可以控制鏈接。它適用於點對點鏈接。

Data Link Functions: Framing, Addressing and Error Control

數據鏈接功能：成幀，尋址和錯誤控制

We look at the framing, addressing, and error control issues directly from the frame format, and then discuss flow control and medium access control. Figure 2.6 depicts the HDLC frame format.

我們直接從幀格式著眼於成幀，尋址和錯誤控制問題，然後討論流控制和媒體訪問控制。圖2.6描述了HDLC幀格式。

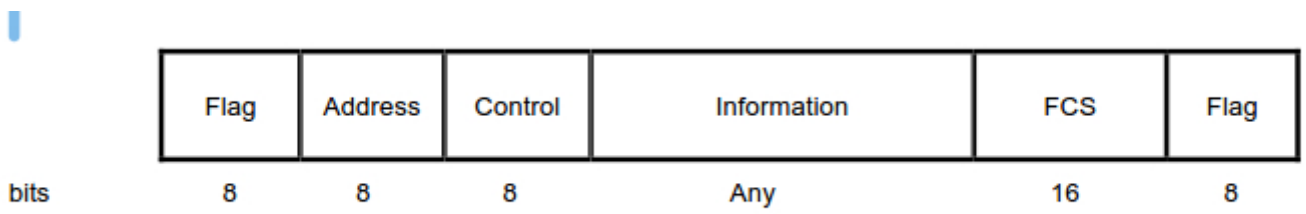


Figure 2.6 HDLC frame format.

Flag: The value is fixed at 01111110 to delimit the beginning and the end of the frame. As illustrated in Section 2.1.1, bit stuffing is used to avoid ambiguity between actual data and the flag value.

標誌：該值固定為01111110，以界定幀的開始和結束。如2.1.1節所示，位填充用於避免實際數據與標誌值之間的歧義。

Address: The address indicates the secondary station involved in transmission,

地址：該地址指示參與傳輸的從站，

particularly in point-to-multipoint situation.

特別是在點對多點的情況下。

A secondary station works under the control of the primary station, as mentioned in the HDLC operation.

從站在主站的控制下工作，如HDLC操作中所述。

Control: This field indicates the frame type as well as other control information such as sequence numbers.

控制：此字段指示幀類型以及其他控制信息，例如序列號。

HDLC has three types of frames: Information,

HDLC具有三種類型的幀：信息，

Supervisory, and Unnumbered. We will look at them deeper later.

主管，無編號。我們稍後將更深入地研究它們。

Information: The information field can be of arbitrary length in unit of bits.

信息：信息字段可以是任意長度，以位為單位。

It carries the data payload to be transmitted.

它攜帶要傳輸的數據有效載荷。

FCS: A 16-bit CRC-CCITT code is used. HDLC allows both positive and negative acknowledgements. The error control in HDLC is complex.

FCS：使用16位CRC-CCITT代碼。 HDLC允許肯定和否定確認。 HDLC中的錯誤控制很複雜。

Positive acknowledgements can indicate a successful frame or all frames up to a point,

肯定的確認可以表示成功的幀或直至某一點的所有幀，

while negative acknowledgements can reject a received frame or a specified frame.

否定確認可以拒絕接收到的幀或指定的幀。

We do not go into the details. Interested readers are encouraged to read on from our list in further reading.

我們不贅述。我們鼓勵有興趣的讀者從我們的清單中繼續閱讀。

Data Link Functions: Flow Control

數據鏈接功能：流量控制

Flow control in HDLC is simple.

HDLC中的流控制很簡單。

The transmitter keeps a counter to record the sequence number of the next frame to be sent. On the other side,

發送器保留一個計數器，以記錄要發送的下一幀的序列號。另一方面，

the receiver keeps a counter to record the expected sequence number,

接收器保留一個計數器來記錄預期的序列號，

and checks whether the sequence number received matches its expectation.

並檢查接收到的序列號是否符合預期。

If the sequence number is correct and the frame is not garbled, the receiver increases its counter by one

如果序列號正確並且幀沒有亂碼，則接收器的計數器加一

and acknowledges the sender by transmitting a message containing the next expected sequence.

並通過發送包含下一個預期序列的消息來確認發送方。

If the received frame is unexpected, or an error is detected,

如果收到的幀意外，或檢測到錯誤，

the frame is dropped and a negative acknowledgement is sent back to the sender.

幀被丟棄，否定確認被發送回發送者。

Frame Type

鏡框類型

The above functions are achieved through various kinds of frames.

以上功能是通過各種框架實現的。

An information frame, called I-frame, carries data from the upper layer and some control information, which has two sequence numbers of three bits to indicate the sequence number of itself and the acknowledged sequence number from the receiver.

稱為I幀的信息幀承載來自上層的數據和一些控制信息，該信息具有兩個三位的序列號，以指示其自身的序列號和來自接收器的已確認序列號。

These sequence numbers are for flow-control and error-control purposes,

這些序列號用於流量控制和錯誤控制目的，

as mentioned above. A poll/final (P/F) is also in the control information to indicate a poll from the primary or the last response from the secondary.

正如剛才提到的。控制信息中還包含輪詢/最終（P / F），以指示來自主服務器的輪詢或來自輔助服務器的最後響應。

A supervisory frame, called S-frame, carries control information only.

監控幀稱為S幀，僅承載控制信息。

As we have seen in the illustration of HDLC frame, both positive and negative acknowledgements are supported for error control. Once there is an error,

正如我們在HDLC幀的圖示中所看到的，錯誤控制支持正確認和負確認。一旦有錯誤，

the transmitter can either retransmit all outstanding frames or only the erroneous frame, as specified in the control information. The receiver can also ask for a temporary stop to the transmitter with an S-frame.

根據控制信息中的規定，發送器可以重發所有未完成的幀，也可以只重發錯誤的幀。接收器還可以通過S幀請求發送器暫時停止。

An unnumbered frame, called U-frame, is also used for control purpose, but it does not carry any sequence number, so is the name derived. It includes miscellaneous commands for mode settings, information transfer, and recovery,

未編號的幀（稱為U幀）也用於控制目的，但不攜帶任何序列號，名稱也是如此。它包括用於模式設置，信息傳輸和恢復的其他命令，

but we do not go into details here.

但是我們在這裡不做詳細介紹。

2.3.2 Point-to-Point Protocol (PPP)

2.3.2點對點協議（PPP）

The PPP is a standard protocol defined by IETF to carry multi-protocol packets over a point-to-point link. It is widely used for dial-up modems and leased lines.

PPP是由IETF定義的標準協議，用於通過點對點鏈路承載多協議數據包。它廣泛用於撥號調製解調器和專線。

To carry multi-protocol packets, it has three main components:

為了承載多協議數據包，它具有三個主要組件：

1. An encapsulation method to cap packets from the network layer.

1.一種封裝方法，用於限制來自網絡層的數據包。

2. A Link Control Protocol (LCP) to handle the cycle of connection setup,

2.鏈路控制協議（LCP），用於處理連接建立的周期，

configuration, and tear-down.

配置和拆卸。

3. A Network Control Protocol (NCP) to configure different network-layer options.

3.網絡控制協議（NCP），用於配置不同的網絡層選項。

We first look at the PPP operation and then study its functions.

我們首先查看PPP操作，然後研究其功能。

PPP Operation

PPP運作

In a service subscription scenario, before entering the HDLC-like operation,

在服務訂閱方案中，在進入類似HDLC的操作之前，

PPP needs to login and configure before sending any data packets.

PPP需要先登錄和配置，然後再發送任何數據包。

The PPP operation follows the phase diagram in Figure 2.7. PPP first sends LCP packets to establish and test the connection. After the connection is setup, the peer may authenticate itself before any network layer packets are exchanged.

PPP操作遵循圖2.7中的階段圖。 PPP首先發送LCP數據包以建立和測試連接。建立連接後，對等方可以在交換任何網絡層數據包之前對其進行身份驗證。

Then PPP starts to send NCP packets to configure one or more network layer protocols.

然後，PPP開始發送NCP數據包以配置一個或多個網絡層協議。

Once the configuration is done, the network layer packets can be sent over the link before the connection goes to the terminate phase.

完成配置後，可以在連接進入終止階段之前通過鏈路發送網絡層數據包。

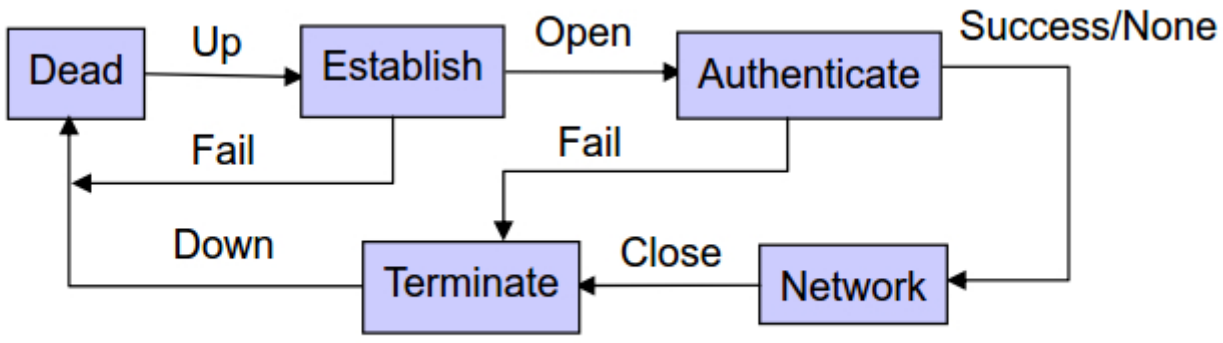


Figure 2.7 Phase diagram of PPP connection setup and tear-down.

We explain each major transition in the diagram as follows:

我們解釋圖中的每個主要過渡如下：

Dead to Establish: The transition is invoked by carrier detection or network administrator configuration to use a physical link.

待定：遷移由運營商檢測或網絡管理員配置調用以使用物理鏈路。

Establish to Authenticate: The LCP starts to set up the connection by exchanging configuration packets. All options not negotiated are assumed to be default values. Only options independent of the network layer are negotiated, and

建立身份驗證：LCP通過交換配置數據包開始建立連接。所有未協商的選項均假定為默認值。僅協商獨立於網絡層的選項，並且

the options about network layer configuration are left to the NCP.

有關網絡層配置的選項留給了NCP。

Authenticate to Network: Authentication is optional in PPP. If required in the link establishment phase, the transition will come to the authentication phase.

對網絡進行身份驗證：在PPP中身份驗證是可選的。如果在鏈接建立階段需要，則過渡將進入身份驗證階段。

If the authentication fails, the connection will be terminated; otherwise, the proper NCP starts to negotiate each network layer protocol.

如果認證失敗，則連接將終止；否則，適當的NCP將開始協商每個網絡層協議。

Network to Terminate: The termination happens in many situations, including the loss of carrier, authentication failure, expiration of an idle connection, user termination, etc. The LCP is responsible for exchanging Terminate packets to close the connection and later the PPP tells the network layer protocol to close.

網絡終止：終止發生在許多情況下，包括運營商丟失，身份驗證失敗，空閒連接期滿，用戶終止等。LCP負責交換終止數據包以關閉連接，稍後PPP通知網絡層協議關閉。

There are three classes of LCP frames: Configuration, Termination and Maintenance. A pair of Configure-request and Configure-ack can open a connection. The options such as maximum receive unit or authentication protocol

LCP框架分為三類：配置，終止和維護。一對Configure-request和Configure-ack可以打開一個連接。選項，例如最大接收單位或身份驗證協議

are negotiable during the connection setup. Table 2.5 summarizes the other functions. The LCP frame is a special case of the PPP frame. Therefore, before we look at the LCP frame format, we first introduce the PPP frame format below.

在建立連接期間可以協商。表2.5總結了其他功能。 LCP幀是PPP幀的特例。因此，在研究LCP幀格式之前，我們首先介紹以下PPP幀格式。

Table 2.5 The LCP frame types

Class	Type	Function
Configuration	Configure-request	Open a connection by giving desired changes to options
	Configure-ack	Acknowledge Configure-request

	Configure-nak	Deny Configure-request because of unacceptable options
	Configure-reject	Deny Configure-request because of unrecognizable options
Termination	Terminate-request	Request to close the connection
	Terminate-ack	Acknowledge Terminate-request
Maintenance	Code-reject	Unknown requests from the peer
	Protocol-reject	Unsupported protocol from the peer
	Echo-request	Echo back the request (for debugging)
	Echo-reply	The echo for Echo-request (for debugging)
	Discard-request	Just discard the request (for debugging)

Data Link Functions: Framing, Addressing, and Error Control

數據鏈接功能：成幀，尋址和錯誤控制

The PPP frame is encapsulated in an HDLC-like format, as depicted in Figure 2.8. The flag value is exactly the same as in HDLC. It serves as the delimiter for framing.

PPP幀以類似HDLC的格式封裝，如圖2.8所示。標誌值與HDLC中的標誌值完全相同。它用作幀的定界符。

Flag 01111110	Address 11111111	Control 00000011	Protocol	Information	FCS	Flag 01111110
bits 8	8	8	8 or 16	Any	16 or 32	8

Figure 2.8 PPP frame format

The differences from an HDLC frame are summarized below:

與HDLC幀的區別總結如下：

1. The address is fixed at the value 11111111, which is the all-stations address in the HDLC format. Since only two peers are in a point-to-point link, there is no need to indicate an individual station address at all.

1.該地址固定為值11111111，這是HDLC格式的所有站地址。由於在點對點鏈接中只有兩個對等點，因此根本不需要指示單個站點地址。

2. The control code is fixed at 00000011, which corresponds to an unnumbered frame in the HDLC format. This implies that no sequence numbers and acknowledgement are used in the PPP by default. Interested readers are

2.控制碼固定為00000011，對應於HDLC格式的未編號幀。這意味著默認情況下，PPP中不使用任何序列號和確認。感興趣的讀者是

referred to RFC 1663 that defines an extension to make the PPP connection reliable.

參考RFC 1663，RFC 1663定義了使PPP連接可靠的擴展。

3. A Protocol field is added to indicate what type of network layer protocol, say IP or IPX the frame is carrying. The field length is 16 bits by default, but it can be reduced to 8 bits using the LCP negotiation.

3.添加了"協議"字段，以指示幀承載的是哪種類型的網絡層協議，例如IP或IPX。默認情況下，字段長度為16位，但是可以使用LCP協商將其減小為8位。

4. The maximum length of the Information field is 1500 bytes by default. The value is called the Maximum Receive Unit (MRU). Other values for MRU are negotiable.

4.默認情況下，信息字段的最大長度為1500字節。該值稱為最大接收單位（MRU）。 MRU的其他值可以協商。

5. The default FCS is 16 bits long, but can be extended to 32 bits through the LCP negotiation. The receiver drops the received frame if an error is detected. The responsibility of retransmission falls on the upper-layer protocols.

5.默認FCS為16位長，但可以通過LCP協商擴展為32位。如果檢測到錯誤，則接收器丟棄接收到的幀。重傳的責任落在上層協議上。

Data Link Functions: No Flow Control and Medium Access Control

數據鏈接功能：無流量控制和介質訪問控制

Because PPP is full-duplex and only two stations are in a point-to-point link,

由於PPP是全雙工的，並且點對點鏈路中只有兩個站，

no medium access control is necessary. On the other hand, PPP does not provide flow control, which is left to upper-layer protocols.

無需介質訪問控制。另一方面，PPP不提供流控制，而流控制則留給上層協議。

LCP and NCP negotiation

LCP和NCP協商

The LCP frame is a PPP frame with the Protocol field 0xc021, where 0x stands for a hexadecimal number. The negotiation information is embedded in the Information field as four main fields. They are Code to indicate the LCP type,

LCP幀是具有協議字段0xc021的PPP幀，其中0x代表十六進制數。協商信息作為四個主要字段嵌入到"信息"字段中。它們是表示LCP類型的代碼，

Identifier to match requests and replies, Length to indicate the total length of the four fields, and Data to carry the negotiation options.

用於匹配請求和答復的標識符，用於指示四個字段的總長度的長度，以及用於攜帶協商選項的數據。

Since IP is the dominating network-layer protocol in the Internet, we are particularly interested in IP over PPP. We will soon introduce NCP for IP – Internet Protocol Control Protocol (IPCP) in the next subsection.

由於IP是Internet中主要的網絡層協議，因此我們對PPP上的IP特別感興趣。我們很快將在下一部分中介紹用於IP的NCP – Internet協議控制協議（IPCP）。

2.3.3 Internet Protocol Control Protocol (IPCP)

2.3.3 Internet協議控制協議（IPCP）

IPCP is a member of NCPs to configure IP over PPP. PPP first establishes a connection by LCP, and then uses NCP to configure the network layer protocol it carries.

IPCP是NCP的成員，用於配置PPP上的IP。 PPP首先通過LCP建立連接，然後使用NCP配置其承載的網絡層協議。

After the configurations, data packets can be transmitted over the link.

配置完成後，可以通過鏈路傳輸數據包。

IPCP uses a similar frame format as the LCP. Its frame is also a special case of the PPP frame, with the Protocol field set to 0x8021. The exchange mechanism is the same as that in the LCP. Through IPCP, IP modules on both peers can be enabled, configured, and disabled.

IPCP使用與LCP類似的幀格式。它的幀也是PPP幀的特例，"協議"字段設置為0x8021。交換機制與LCP中的交換機制相同。通過IPCP，可以在兩個對等方上啟用，配置和禁用IP模塊。

IPCP provides the configuration options: IP-Addresses,

IPCP提供了以下配置選項：IP地址，

IP-Compression-Protocol, and IP-Address. The first is obsolete and is replaced by the third.

IP壓縮協議和IP地址。第一個已過時，已被第三個取代。

The second indicates the use of Van Jacobson's TCP/IP header compression. The third allows the peer to provide an IP address to be used on the local end. After IPCP negotiation, normal IP packets can be transmitted over the link with the Protocol field set to 0x0021 on the PPP frame.

第二個指示使用Van Jacobson的TCP / IP標頭壓縮。第三個允許對等方提供要在本端使用的IP地址。經過IPCP協商後，可以在PPP幀上將協議字段設置為0x0021的鏈路上傳輸普通IP數據包。

Open Source Implementation 2.4: PPP

開源實施2.4：PPP

The Structure of PPP Driver and pppd

PPP驅動程序和pppd的結構

The implementation of PPP in Linux is primarily composed of two parts: the data-plane PPP driver and the control-plane PPP daemon (PPPd). A PPP driver establishes a network interface and passes packets between the serial port, the kernel networking code and the PPP daemon, as illustrated in Figure 2.8. A PPP

Linux中PPP的實現主要由兩部分組成：數據平面PPP驅動程序和控制平面PPP守護程序（PPPd）。 PPP驅動程序建立網絡接口，並在串行端口，內核網絡代碼和PPP守護程序之間傳遞數據包，如圖2.8所示。購買力平價

driver handles the functions in the data link layer described in previous subsections. PPPd negotiates with the peer to establish the link and sets up the PPP network interface.

驅動程序處理前面小節中描述的數據鏈路層中的功能。 PPPd與對等方協商以建立鏈接並建立PPP網絡接口。

It also supports authentication, so it can control which other systems may establish a PPP connection and specify their IP addresses.

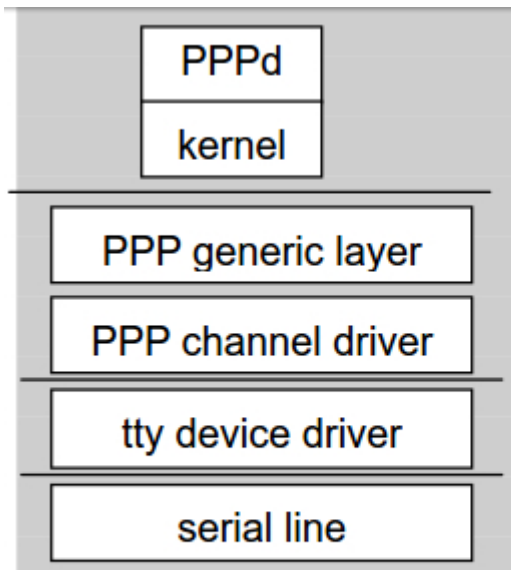
它還支持身份驗證，因此它可以控制哪些其他系統可以建立PPP連接並指定其IP地址。

PPP Driver

PPP驅動程序

A PPP driver is made of the PPP generic layer and the PPP channel driver, as shown in Figure 2.9.

PPP驅動程序由PPP通用層和PPP通道驅動程序組成，如圖2.9所示。



Component	Function
PPPd	handles control-plane packets
Kernel	handles data-plane packets
PPP generic layer	handles PPP network interface , /dev/ppp device, VJ compression , multilink
PPP channel driver	handles encapsulation and framing

Figure 2.9 PPP software architecture.

There are asynchronous and synchronous PPP drivers in Linux.

Linux中有異步和同步PPP驅動程序。

Their difference is in PPP channel driver. Data exchange between the synchronous PPP channel driver and the tty device driver is frame oriented, while that between the asynchronous PPP channel driver and the tty device drivers is byte oriented.

它們的區別在於PPP通道驅動程序。同步PPP通道驅動程序和tty設備驅動程序之間的數據交換是面向幀的，而異步PPP通道驅動程序和tty設備驅動程序之間的數據交換是字節的。

One may ask: “Why is the Ethernet implemented in hardware, but the PPP in software?” PPP is usually used on telephone lines. Due to the relatively low bandwidth, software implementation for the link-layer packet processing is sufficient to fit the speed of the link. Ethernet is much faster, and should be implemented in hardware. Thus, if PPP is to be applied on high speed links, parts of it would need hardware implementations.

有人可能會問：“為什麼在硬件中實現以太網，而在軟件中實現PPP？” PPP通常用於電話線上。由於帶寬相對較低，用於鏈路層數據包處理的軟件實現足以適應鏈路的速度。以太網速度要快得多，應該以硬件實現。因此，如果將PPP應用於高速鏈路，則其中的一部分將需要硬件實現。

2.3.4 PPP over Ethernet (PPPoE)

2.3.4以太網PPP（PPPoE）

The Need of PPPoE As Ethernet technology becomes cheap and dominant, it is not uncommon that users set up their own Ethernet LAN in home or office. On the other hand,

PPPoE的需求隨著以太網技術變得越來越便宜和占主導地位，用戶在家中或辦公室中建立自己的以太網LAN並不少見。另一方面，

broadband access technologies, say ADSL, has become a common method to access the Internet from home or office.

寬帶接入技術，例如ADSL，已經成為從家里或辦公室訪問Internet的常用方法。

Users on an Ethernet LAN access the Internet through the same broadband bridging devices, so service providers desire a method to have access control and billing on a per-user basis,

以太網LAN上的用戶可以通過相同的寬帶橋接設備訪問Internet，因此服務提供商希望有一種方法可以對每個用戶進行訪問控制和計費，

just similar to conventional dial-up services.

與傳統的撥號服務類似。

PPP has conventionally been a solution to build point-to-point relationship between peers, but an Ethernet network involves multiple stations.

PPP通常是在對等點之間建立點對點關係的解決方案，但是以太網網絡涉及多個站點。

The PPP over Ethernet protocol (PPPoE) is designed to coordinate the two conflicting philosophies.

以太網上的PPP協議（PPPoE）旨在協調兩種衝突的理念。

It creates a virtual interface on an Ethernet interface so that individual station on a LAN can establish a PPP session with a remote PPPoE server,

它在以太網接口上創建一個虛擬接口，以便LAN上的各個站點可以與遠程PPPoE服務器建立PPP會話，

known as Access Concentrator (AC) located in the ISP through common bridging devices. Each user on the LAN sees a PPP interface just like that seen in the dial-up service,

通過通用橋接設備位於ISP中的稱為訪問集中器（AC）。局域網中的每個用戶都可以看到PPP接口，就像在撥號服務中看到的一樣，

but the PPP frames are encapsulated in the Ethernet frames. Through PPPoE, the user's computer obtains an IP address, and the ISP can easily track the IP address to a specific user name and password.

但是PPP幀封裝在以太網幀中。通過PPPoE，用戶計算機可以獲得IP地址，ISP可以輕鬆地將IP地址跟踪到特定的用戶名和密碼。

PPPoE Operation

PPPoE操作

The PPPoE runs in two stages: the Discovery stage and the PPP Session stage.

PPPoE分兩個階段運行：發現階段和PPP會話階段。

In the Discovery stage, the MAC address of the access concentrator is discovered.

在發現階段，發現訪問集中器的MAC地址。

A unique PPPoE session identifier is also assigned to the session.

唯一的PPPoE會話標識符也分配給該會話。

Once the session is established, both peers enter the PPP Session stage and do exactly what a PPP session does, say LCP negotiation.

建立會話後，兩個對等方都進入PPP會話階段，並完全執行PPP會話的操作，例如LCP協商。

The Discovery stage proceeds in the following four steps:

發現階段按以下四個步驟進行：

1. The station to access the Internet broadcasts an Initiation frame to ask for remote access concentrators to return their MAC addresses.

1.訪問Internet的站點廣播一個Initiation幀，以請求遠程訪問集中器返回其MAC地址。

2. The remote access concentrators respond their MAC addresses.

2.遠程訪問集中器響應其MAC地址。

3. The original station selects one access concentrator, and sends a Session-Request frame to the selected access concentrator.

3.原始站點選擇一個訪問集中器，然後將會話請求幀發送到所選的訪問集中器。

4. The access concentrator generates a PPPoE session identifier and returns a Confirm frame with the id.

4.訪問集中器生成PPPoE會話標識符，並返回帶有ID的Confirm幀。

The PPP Session stage runs in the same way as a normal PPP session,

PPP會話階段的運行方式與普通PPP會話相同，

as explained in Section 2.2.2, only being carried on the Ethernet frames. When the LCP terminates a PPP session,

如第2.2.2節中所述，僅在以太網幀上承載。當LCP終止PPP會話時，

the PPPoE session is torn down as well. New PPP session requires a new PPPoE session starting from the Discovery stage.

PPPoE會話也被拆除。新的PPP會話需要從發現階段開始的新的PPPoE會話。

A normal PPP termination process can terminate a PPPoE session. PPPoE allows an explicit Terminate frame to close a session sent by either the initiating station or the access concentrator. Once the Terminate frame is sent or received,

正常的PPP終止過程可以終止PPPoE會話。 PPPoE允許顯式的Terminate幀關閉發起站或訪問集中器發送的會話。發送或接收終止幀後，

no further frame transmission is allowed, even for normal PPP termination frames.

即使對於普通的PPP終止幀，也不允許進一步的幀傳輸。