Networking
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### 1. Networks

#### Layering Models

Why seven layers in the ISO model?

History is a trifle vague on this, but it seems that IBM had a seven layer protocol and managed to persuade the ISO committee in charge of the model

Some people advocate more layers: e.g., splitting the hardware layer up

For example, a sublayer describing the physical medium, such as copper or fibre; and a sublayer describing the signals in that medium, such as various kinds of electrical signalling

**Exercise** Reality is complicated. Read IEEE 802 to see how the physical layer can be split into three sublayers; and the link layer can be split into two sublayers

### 2. Networks

#### The Internet Model

Others want fewer layers. A good example is the Internet Model

This is a four layer model, developed post-hoc after the Internet Protocol had gained prominence (RFC1122)

* Link Layer
* Network Layer
* Transport Layer
* Application Layer

### 3. Networks

#### The Internet Model

We shall describe this model, together with its primary instance TCP/IP

Take care to distinguish between the model and the instance

They often get confused as they seem so similar

It is possible, though unlikely, that there could be another network protocol, not TCP/IP, based on the four layer Internet model

### 4. Networks

#### The Internet Model: Link Layer

The Internet link layer corresponds to the OSI physical plus data link layers

The model does not say much about this layer, only that it has to be capable of sending and receiving the next layer packets

So what you do with your hardware is pretty much open

TCP/IP many realisations here, including Ethernet, VDSL and Wi-Fi

And pigeons

### 5. Networks

#### The Internet Model: Network Layer

Also known as the *Internet* layer, the network layer handles the movement of packets, particularly routing

This directly corresponds to the OSI network layer

In TCP/IP, the *Internet Protocol* (IP) is defined in this layer

IP is an *unreliable* protocol. This is a technical term that means that it does not guarantee delivery of packets

$unreliable=not guaranteed reliable$

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#### Aside: Reliability

Sometimes it is better to deal with an occasional lost packet than to hold up the system while the lost packet is re-requested and resent, e.g., video, where fast delivery is more important than accurate delivery

So it is quite useful to have a “unreliable” delivery sometimes

A lot of Internet hardware is actually fairly reliable (non-technical sense) these days

But wireless (Wi-Fi, etc.) and some wired (DSLs) are more unreliable than you might think

### 7. Networks

#### The Internet Model: Transport Layer

The transport layer corresponds to the OSI transport layer, providing a flow of packets between source and destination

In TCP/IP, two protocols are in this layer: the *transmission control protocol* (TCP) and the *user datagram protocol* (UDP)

### 8. Networks

#### The Internet Model: Transport Layer

TCP is a *reliable* (guarantees delivery) protocol

It makes a reliable layer out of a potentially unreliable IP underneath by a complex mechanism of packet acknowledgements

We don’t always want to pay the non-trivial cost of that mechanism, so the other protocol, UDP, is not reliable

Actually, it is reliable as the underlying layer, IP, is reliable

And IP is as reliable as its underlying physical/datalink layer is reliable

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#### The Internet Model: Transport Layer

UDP was devised long after TCP when it was realised how useful unreliable protocols can be: this is why the protocol set is called “TCP/IP”, as that was the entire protocol set for a fair while

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#### The Internet Model: Transport Layer

We shall see packets have a header field indicating what the protocol of the data in the packet is

TCP has protocol number 6

UDP has protocol number 17

**Exercise** Have a look at “Protocol Numbers” at
<https://www.iana.org/assignments/protocol-numbers/protocol-numbers.xhtml>

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#### The Internet Model: Application Layer

The application layer covers (roughly) the OSI session, presentation and application layers

This means, in particular, Internet *applications* must take care over presentation issues if they want to be completely interoparable

Many forget this, e.g., many programmers forget that not all machines represent integers in the same way and so the bit pattern they use for the number they want to send is (mis)interpreted as a different number by the receiver

### 12. Networks

#### The Internet Model: Application Layer

In terms of implementation, typically an OS kernel will implement everything below the application layer (TCP, UDP, IP, Ethernet, Wi-Fi, etc.)

This is because they use system resources that must be shared fairly amongst applications

Anything *above* the transport layer must be done by the application programmer in their application code

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#### The Internet Model: Application Layer

So a typical email application will need to apply a presentation encapsulation and add application layer headers (To, From, etc.)

The Multipurpose Internet Mail Extensions (MIME) standard is a way to encode data (e.g., text, sound, pictures, video) in a safe way

Originally developed in the context of email, it is now used in other areas like Web page delivery where there are mixed kinds of data to transmit

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#### The Internet Model: Application Layer

Similarly for the session layer

If a persistent session is needed, the application must code it

Many applications, like Web browsers using HTTP, don’t

Note: if the TCP/IP had session management, applications would get this “for free”

The counter-argument is that many applications do not want session management, and should not have to pay the overhead of supporting it

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#### The Internet Model: Application Layer

In the real world, each application (running over TCP/IP) that needs session management has to re-implement it for itself

Of course, libraries of code exist to do these “missing” things (sessions, presentation and so on), but the programmer must write the code to incorporate them

### 16. Networks

Example of layering in practice: how an email might be transmitted over an Ethernet

* We start with the text of the email
* Application: the email application transforms the text using a MIME encoding (presentation)
* Application: the email application adds an *envelope* header (From, To, etc.)
* Transport: TCP adds its header (reliability)
* Network: IP adds its header (routing)
* Datalink: Ethernet adds a header (local routing) and a trailer (checksum)
* Physical: The bits are transformed using a 4B/5B encoding to smooth the bit patterns and are sent using a three-level electrical coding MLT-3 (physical)

### 17. Networks

Going through all these in detail is the content of this Unit

### 18. Networks

We have two layering models, ISO and Internet, two approaches to designing a standard

How do they compare?

### 19. Networks

#### Layering Models



OSI vs. Internet Models

### 20. Networks

#### Layering Models

Comparing the two models:

* OSI was developed before an implementation; the Internet Model was created *after* TCP/IP
* OSI make a clear distinction between model and implementation; Internet is fuzzy
* OSI is general and can apply to many systems; Internet is specific, namely to TCP/IP
* Implementations following standards following the OSI model were dire; TCP/IP is wildly successful

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#### Layering Models

Problems with the Internet Model (*not* TCP/IP) include

* it is only good for describing TCP/IP
* the physical and data link layers are merged; this makes it difficult to talk about, say, copper vs. optical fibre installations

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#### Layering Models

Non-problems include

“OSI is slower as data has to go through more layers”

This is confusing the model with the implementation and ignoring the standard in between them

An implementation need not have 7 separate modules: it only needs to *behave as if it did*

Early implementations of a standard derived from OSI made this mistake

There are good CS reasons why we should do this separation, but practically we have to make tradeoffs between maintainability and speed

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#### Layering Models

“OSI has larger encapsulation overhead as data has to go through more layers”

As above

And you don’t *have* to add a header at every layer: it depends on what the standard requires

The model doesn’t *require* anything

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#### Layering Models

“There are no decent implementations of OSI”

Again, confusing a model with a standard

And TCP/IP can be regarded a standard that fits the OSI model, anyway

If you squint a bit

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#### TCP/IP

The OSI model is widely used; the OSI protocols never

The Internet model is rarely used; the TCP/IP protocols are everywhere

The main reason that TCP/IP is so successful is that its standards (RFCs) are open and freely available: anyone can join in

Furthermore, the code was also free and widely available

Not brilliant quality, but at least it worked…

### 26. Networks

#### TCP/IP

Networks before the Internet tended to be closed and proprietary, where you had to pay to get in

But all these failed to get critical mass: even Microsoft failed to get their own alternative to the Internet off the ground and they had (grudgingly) to join with the rest of the world in using TCP/IP

### 27. Networks

#### Layering

Other layering models exist, e.g., *Tanenbaum’s Five Layer Model*

* Physical
* Data link
* Network
* Transport
* Application

Still missing the essential presentation layer, but a lot more useful in a world where the physical layer is often changed, e.g., 1Gb Ethernet to Wi-Fi

### 28. Networks

#### Layering Models



Cup and string network

**Exercise** identify the OSI and Internet layers as they apply to a cup-and-string network

**Exercise** Read section 3 of RFC3439