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Intro To The Architecture Of The Internet

Lecture Outline

1. The Internet: A Quick Overview
2. Transmission Control Protocol / Internet Protocol (TCP / IP)
3. TCP/IP: Link Layer
4. TCP/IP: Internetwork Layer
5. TCP/IP: Transport Layer
6. TCP/IP: Application Layer
7. OSI vs TCP/IP

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The Internet: A Quick Overview

➡ The term “Internet” is derived from “**internetworking**”.

➡ Internetworking: connecting many networks with each other.

Many computers connect to the local network, and many local networks are connected with each other through “the Internet”.

➡ The core of the Internet is a network of **routers** that move **packets** from many sources to many destinations.

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Routers

➡ router: specialized computer that knows how to route packets along a path, from some source to some destination.

➡ Each router has a "**routing table**", or a map of network numbers to outbound links

The routing table is used to properly route packets based on the destination address (IP address) for each incoming packet.

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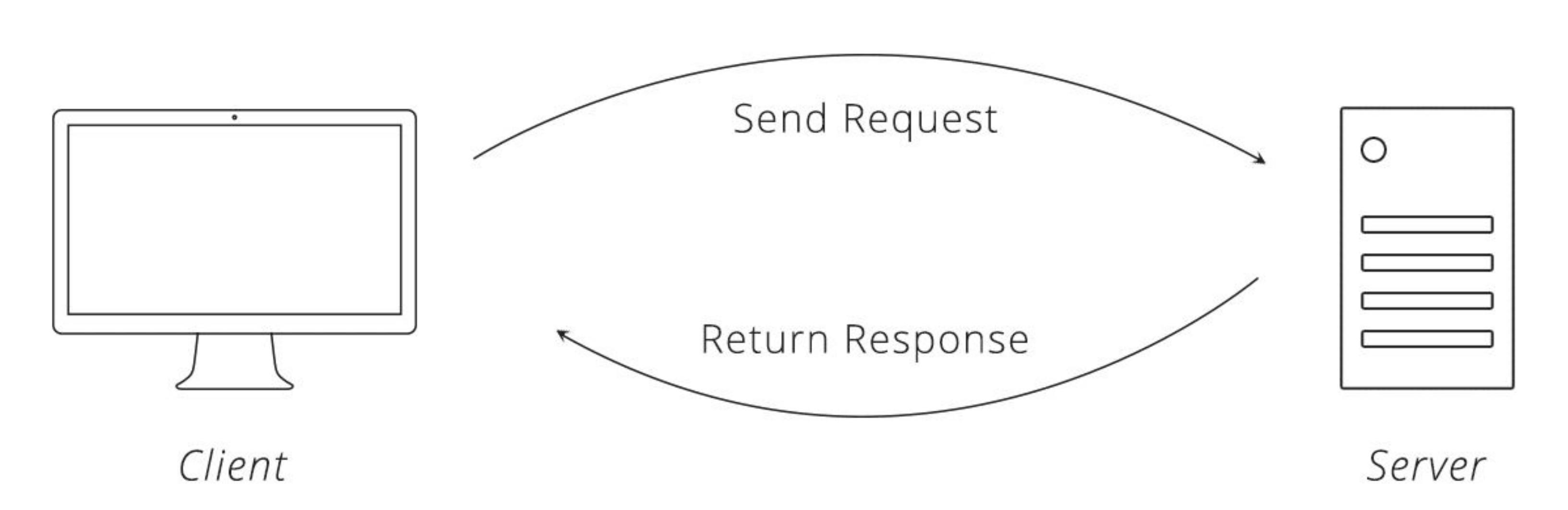
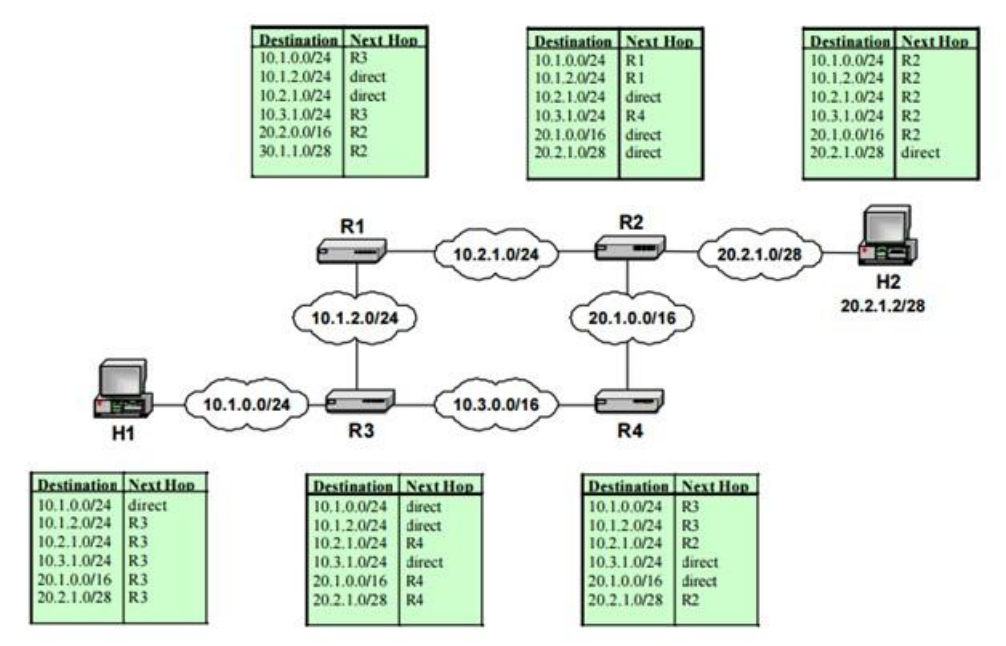
The Request-Response Cycle, Oversimplified



Routers

➡ routing table: a map of network numbers to outbound links, for a given router

➡ It is used to properly route packets based on the destination (IP) address for each incoming packet



Packets

➡ Every packet will go through multiple routers during its journey.

➡ A packet may be part of a larger message.

The larger message is broken into pieces and each piece is sent separately.

➡ Different packets of a message may take different routes as they are passed along.

Therefore, packets for the same message may arrive out of order.

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Packets of Large Messages

➡ Each packet of a multi-packet message includes an "**offset**"

➡ offset: the position of a packet within an overall message

➡ When messages are broken into packets and each packet is sent separately, the sending of the large message does not block the sending of other messages.

The computer alternates sending packets from different messages.

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TCP/IP: Engineering At Its Finest

➡ The big problem that is the Internet was broken down into smaller engineering problems to be solved independently

➡ Engineers broke the problem into 4 smaller problems:

(1) Link

(2) Internetwork

(3) Transport

(4) Application

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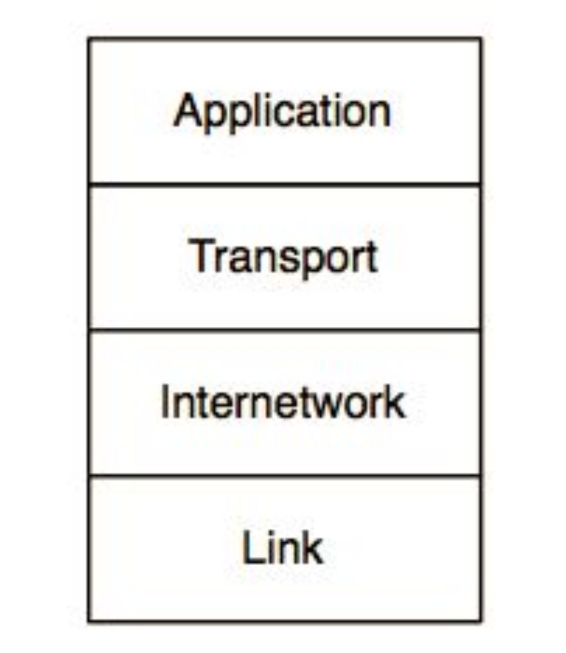
TCP/IP: Engineering At Its Finest

➡ The solution is known as the "**TCP/IP model**", and got its name from:

1. The Transport Control Protocol (TCP) implemented in the Transport layer

2. The Internet Protocol (IP) implemented in the Internetwork layer



An Important Term: “hop”

➡ hop: a single physical network connection.

A packet on the Internet will typically make several “hops” to get from its source computer to its destination.

💻 Let’s see this using `traceroute`

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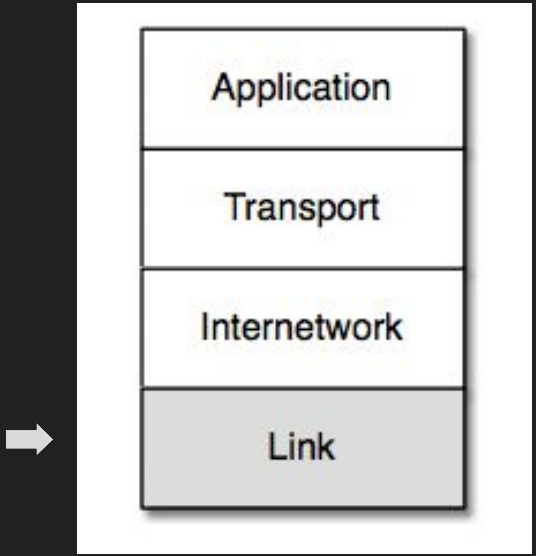
TCP/IP: Link Layer

➡ The "lowest layer" of the Internet Architecture.

Called so because it is closest to the physical network media.



TCP/IP: Link Layer

➡ The Link layer is responsible for:

(1) Connecting a computer to its local network (think printer)

(2) Moving data across a single hop

➡ Examples of Link Layer Technology:

(1) Cell phone ⇔ Cell phone tower

(2) Laptop ⇔ Home/company router

TCP/IP: Link Layer

- ➡ This layer needs to solve two basic problems:

  (1) How to encode and send data across the hop.

  (2) How to cooperate with other computers that might want to send data at the same time.

TCP/IP: Link Layer: Encoding

➡ For WiFi connections, standards detailing the radio frequencies to be used to transmit data and how the data is to be encoded in the radio signal.

➡ For wired connections, standards detailing what voltage to use on the wire and how fast to send the bits across the wire.

➡ For fiber optics connections, standards detailing the frequencies of light to be used and how fast to send the data.

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TCP/IP: Link Layer: Cooperation

➡ If all the computers on the network tried to transmit whenever they had data to send, their messages would collide, and receiving stations would only receive "noise".

➡ There needs to be a fair protocol that allows each computer to wait its turn to use the shared network:

> "Carrier Sense Multiple Access with Collision Detection", or CSMA/CD.

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TCP/IP: Link Layer: Cooperation: CSMA/CD

- “**Carrier Sense Multiple Access**” with “**Collision Detection**”
- Carrier Sense:

  (1) When your computer wants to send data, it first listens to see if another computer is already sending data on the network.

  (2) If the network is not being used, your computer starts sending its data.

  (3) As it is sending data it also listens to see if it can receive its own data. If it receives its own data, it knows that the channel is still clear, and so continues sending.

TCP/IP: Link Layer: Cooperation: CSMA/CD

➡ "**Carrier Sense Multiple Access**" with "**Collision Detection**"

➡ Collision Detection:

(1) If two computers send data at about the same time, the data collides, and your computer receives "noise", not its own data.

This indicates a collision!

(2) When a collision is detected, both computers stop transmitting, each wait a random interval, and retry the transmission.

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TCP/IP: Link Layer: Cooperation: Token-Share

- ➡ There is a different cooperation protocol: token-style networks.
- ➡ Computer needs to be holding token to send data
- ➡ After sending, it gives token back to “base station”
- ➡ Token cycles to other computers before coming back

TCP/IP: Link Layer: Broadcasting / Listening

- All computers near the base station:

  (1) Receive all packets broadcasted by the station.

  (2) Receive all packets sent by nearby computers.

- Each WiFi radio has a “Media Access Control” or “MAC” address:

  This serial number per computer is the distinguishing factor.

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TCP/IP: Link Layer: Broadcasting / Listening

➡ MAC Addresses are assigned by manufacturer of WiFi Radio

➡ They remain same for the life of the Wifi Radio

```
0f:2a:b3:1f:b3:1a
```

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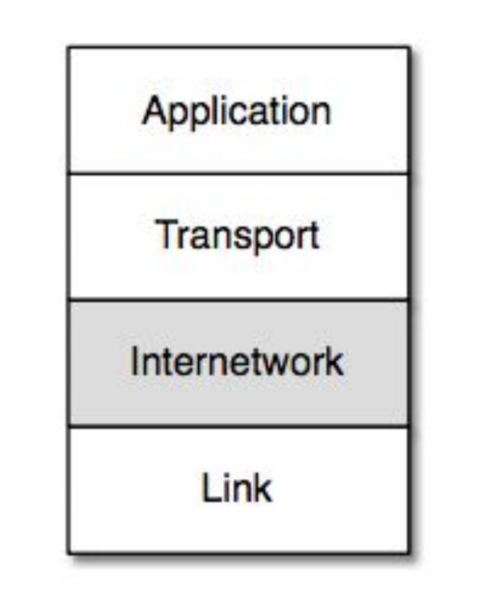
TCP/IP: Internetwork Layer

➡ This layer is responsible for connecting networks with each other.

"Inter" => "between"

➡



TCP/IP: Internetwork Layer

➡ Once a packet makes it across the first hop (link layer), it will be in a router.

➡ Each packet has a source address and destination address.

The router looks at the destination address and sends the packet

"*in the right direction*"

➡ Over many **hops** it reaches a router that knows exact *destination*.

TCP/IP: Internetwork Layer: IP Addresses

➡ There is no relationship between a MAC Address and the location where that computer is connected to the network.

➡ IP address are given to every computer based on where the computer is connected to the Internet.

➡ IP Addresses are originally allocated by one of 5 "**Regional Internet Registries (RIRs)**"

Trickle-down allocation to your "**Internet Service Provider (ISP)**"

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TCP/IP: Internetwork Layer: IP Addresses

- Two versions of IP Addresses:

  (classic) IPv4 addresses: 111.222.3.4

  IPv6 addresses: 2001:0db8:85a3:0042:1000:8a2e:0370:7334

- IPv4: "**111.222**" && "**3.4**"

  Network Number: "**111.222**"
  Host Identifier: "**3.4**"

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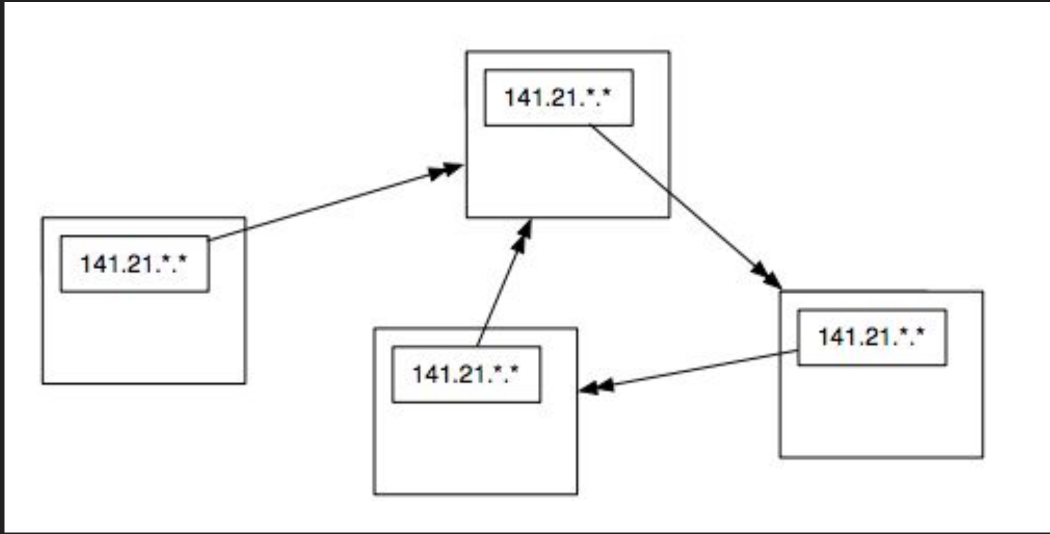
TCP/IP: Internetwork Layer: TTD



A Packet / Routing Vortex

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TCP/IP: Internetwork Layer: TTD

➡ Time To Live (TTL): A number that is stored in every packet that is reduced by one as the packet passes through each router.

➡ When the TTL reaches zero, the packet is discarded.

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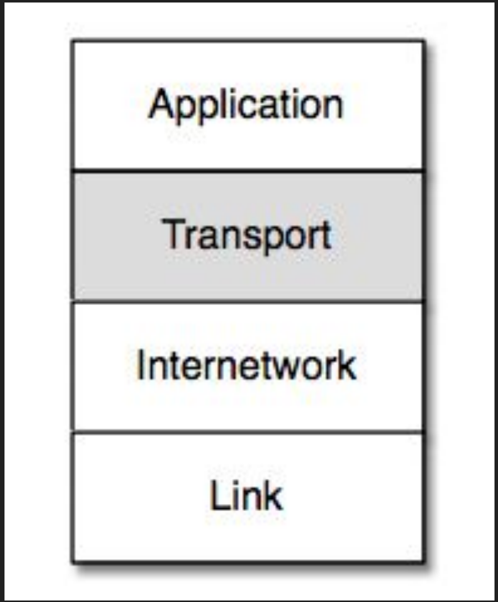
TCP/IP: Transport Layer

➡ The layer that handles reliability and message reconstruction on the destination computer.

➡ 

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TCP/IP: Transport Layer

- ➡ Sometimes packets get lost or badly delayed.
- ➡ Sometimes packets arrive at their destination out of order.

Data Packet Headers

<table>
<tr><td>Bit</td><td>0</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td><td>6</td><td>7</td><td>8</td><td>9</td><td>10</td><td>11</td><td>12</td><td>13</td><td>14</td><td>15</td><td>16</td><td>17</td><td>18</td><td>19</td><td>20</td><td>21</td><td>22</td><td>23</td><td>24</td><td>25</td><td>26</td><td>27</td><td>28</td><td>29</td><td>30</td><td>31</td></tr>
<tr><td>0</td><td colspan="4">Version</td><td colspan="4">IHL</td><td colspan="6">DSCP</td><td colspan="2">ECN</td><td colspan="16">Total Length</td></tr>
<tr><td>32</td><td colspan="16">Identification</td><td colspan="3">Flags</td><td colspan="13">Fragment Offset</td></tr>
<tr><td>64</td><td colspan="8">Time to Live</td><td colspan="8">Protocol</td><td colspan="16">Header Checksum</td></tr>
<tr><td>96</td><td colspan="32">Source IP Address</td></tr>
<tr><td>128</td><td colspan="32">Destination IP Address</td></tr>
<tr><td>160</td><td colspan="16">Options (if IHL > 5)</td><td colspan="16">Padding (If Options length NOT multiple of 32)</td></tr>
</table>

TCP/IP: Transport Layer

➡ As message is reconstructed in Destination Computer:

(1) It delivers the message to the receiving application.

(2) it periodically sends an acknowledgement back to the source.

➡ The source computer must store a copy of the parts of the original message that have been sent

(until the destination computer acknowledges successful receipt of the packets)

TCP/IP: Transport Layer: Window Size

➡ window size: the amount of data the source computer sends before stopping & waiting for acknowledgement

➡ If the acknowledgments come back *quickly*:

Source computer slowly increases the window.

➡ If the acknowledgments come back *slowly*:

Source computer keeps the window size small.

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TCP/IP: Application Layer

➡ The World Wide Web is an application whose protocol is HTTP

➡ “web applications” can be considered as broken into 2 halves:

(1) “web client” (e.g. browsers)

(2) “web server”

➡ They need an “application protocol” that describes how the two halves of the application will exchange messages over the network.

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TCP/IP vs OSI

➡ The TCP/IP model is not the only network model.

➡ The other model commonly used to make sense of network design is called the **Open System Interconnection (OSI)** Model.

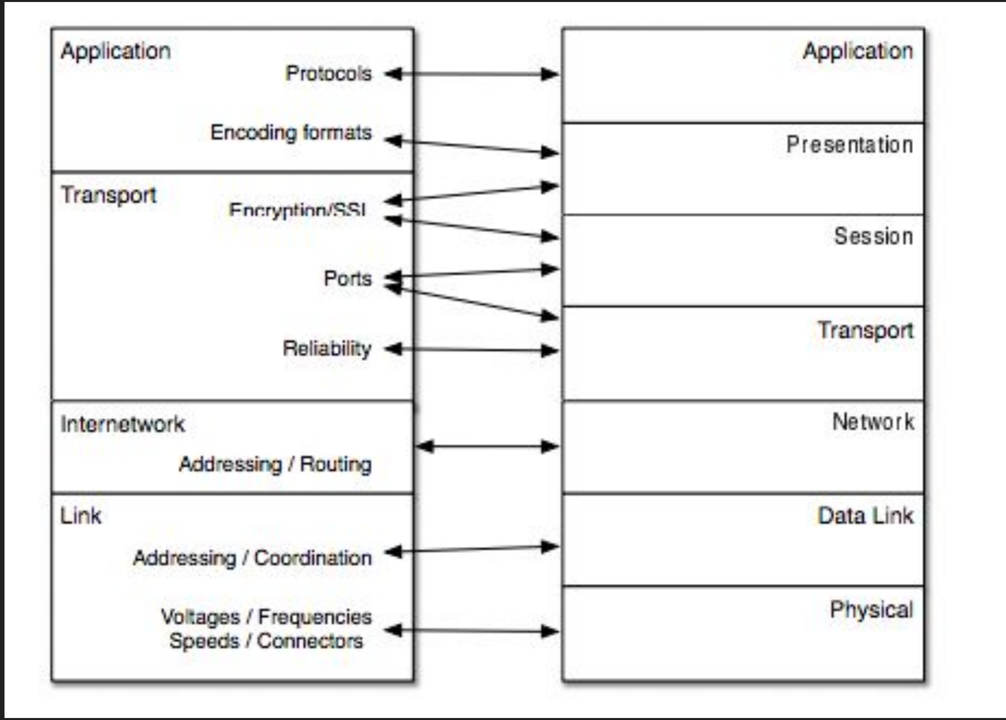
TCP/IP vs OSI

➡ Today, the *OSI* model and the *TCP/IP* model serve different purposes:

(1) **TCP/IP** => an implementation model, guidance for building TCP/IP-compatible network hardware or software.

(2) **OSI** => more of an abstract model that can be used to understand a wide range of network architectures.

TCP/IP vs OSI



Solve the networking problem, split into different sub-problems

Credits

Most Images and the Gist of the Content:

“Introduction to Networking: How the Internet Works”,

by Charles R. Severance

(free eBook in PDF / EPUB at https://www.net-intro.com/)