

# More On Computer Networks

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# 1 Additional Concepts

## 1.1 Process ID

As mentioned in the conclusion of the chapter *Computer Networks*, the essential service of the Internet is to deliver a message without error from the computer corresponding to the source IP address to the computer corresponding to the destination IP address. Once the message has been received, it will be pass to the operating system. The operating system identifies from its PORT ID as well as its Session ID and passes the message to the corresponding process running in the computer.

In the area of computer science, each program running in a computer is called a process. Each process is assigned with a unique number called Process ID. For instance, you have invoked two Chrome applications. Each browser will be associated with an unique process ID. The operating system could thus generate different session IDs for messages to be sent from different browsers.

Application	Process ID	Session ID
Browser X	111	333
Browser X	111	351
Browser X	111	091
Browser Y	272	444
Browser Y	272	301
WORD	101	–

As a process can send more than one message to the Internet, different message could be assigned with different session ID. This table is maintained by the operating system. The operating system can thus generate the IP datagram for a process and pass it to the network card.

Remember that there are background processes running in a computer as well. For instance, one background process is in charge of the operating system update. This process will also be assigned with an unique process ID. This ID can let it connects with the remote server to download the updated patches for operating system update.

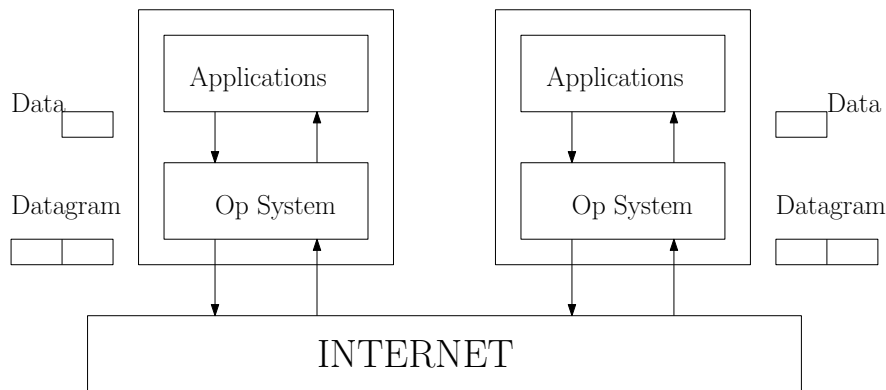


Figure 1: Lower layer provides services to the upper layer.

## 1.2 Client-Server Computing: Layered Model Perspective

In the *Operating System* chapter, the concept of client-server computing has been introduced. The operating system plays a role as a server while the application system plays a role as a client. The operating system provides services to the application systems.

As a matter of fact, this concept can now be extended to describe the role of Internet. But now, the operating system plays a role as a client while the Internet plays a role as a server. The Internet provides message deliver service to the operating systems.

To make it clear! One should understand that the design of this giant computing system is based upon the concept of client-server computing.

1. **Server: Internet; Client: Operating Systems.** Internet serves all the operating systems in which their computers are connected to the Internet.
2. **Server: Operating System; Client: Application Systems.** An operating system serves all the application systems running in the computer.
3. **Server: Application System; Client: Users.** An application system serves all its users who invoke the application system.
4. **Server: User; Client: Customers.** A user of the application system

could be a staff in a firm. He or she works on something to serve for his or her clients (other staffs in the firm or the customers of the firm).

Note that each server does not serve one client only. It serves multiple clients. This layered structure tells us one important phenomena. Some systems (resp. people) play both roles as client and server.

### 1.3 Networking Models

In the literature, there are many layered structures for the TCP/IP model. In the book authored by Andrew S. Tanenbaum<sup>1</sup>, the author states five-layer model. In the book authored by William Stallings<sup>2</sup>, the author states another five-layer model. The open system for interconnection (OSI) model from the International Organization for Standardization (ISO) states a seven-layer model.

Tanenbaum	Stalling	OSI Model
		Application
Application	Application	Presentation Session
Transport	Transport	Transport
Internet	Internet	Network
Network Access	Data Link	Data Link
Physical	Physical	Physical

The bottom four layers could be interpreted as the TCP/IP layer. Presentation layer in the OSI model consists of protocols for character encoding, like ASCII code, and the encryption methods.

These models are reference models for the understanding of the technologies embraced. Besides, it provides the complete picture of the technologies supporting the computer network. Lower layers provides services to the higher layer. For example, the technologies developed in the physical and data link layers are used for providing services for the Internet layer.

<sup>1</sup>Tanenbaum, Andrew S., *Computer Networks*, Prentice Hall, 2003.

<sup>2</sup>Stallings, William, *Data and Computer Communications*, Prentice Hall, 2007.

## 1.4 Port number

In the above networking models, one should see that the layer above the Internet layer is called transport layer. The protocols developed in the layer are responsible for port to port message delivery. That is why it is called transport layer.

In convention, each port is associated with one and only one application protocol. For instance, the message to be delivered for the application systems developed by using hypertext transfer protocol (HTTP) will be assigned with Port 80. The message to be delivered for the application systems developed by using file transfer protocol (FTP) will be assigned with Port 20 or Port 21.

A port number specified in TCP is encoded by a 16 bits long binary number. Therefore, we could have altogether 65535 TCP ports. Many of them have not be used. For any future developed application protocol, developer can select then a number from these port numbers for the application protocol.

## 2 Hypertext Transfer Protocol (HTTP)

In its initial design, one application of Internet is to let people sharing their information or knowledge, in form of web pages. A web page is just like a newspaper article or a technical report. These web pages are collectively called the web resources. The technologies supporting this information sharing application are embraced under the hypertext transfer protocol (HTTP).

Hypertext is a technical term for a document file (equivalently a web page) which contains data other than text. They could be an image, photo, video, audio data and/or links (so-called the hyperlinks) to other information sources. The location of a web resource is called *uniform resource locator* (URL). For instance, the following is the URL of the course homepage.

```
http://web.nchu.edu.tw/~pfsum/CS/cs_index.html
```

To make it work, we need three things. First, a program file contains the information to be shared and to be displayed. Second, a web server manages the requests from the browsers in remote locations and the files to be delivered to the browsers. Third, a reader (i.e. browser) interprets the program file and then generates the output (i.e. webpage) in accordance with

the layout specified in the program. The first two are located in the server side. The third is located in the client side.

The language for generating such program file is a programming language called hypertext markup language (HTML). It is a very simple language for formatting a webpage. Precisely, it is the programming language for *static* webpage.

Today, a website could have many dynamic webpages with various effects. It is because many advanced programming languages have been developed. These languages could support more sophisticated formatting features. Moreover, many more (web) technologies have been developed for advanced uses. Integrated with other protocols, applications like webmail (Gmail for instance), online shopping platform (PC Home for instance) and cloud platform (Google Cloud for instance) are developed. As an introductory course, they will not be covered here. Only the basic HTML will be introduced.

## 2.1 Web server

A web server is a program managing all the web resources available in the machine and handling all the requests from the remote clients for the resources to be delivered. Technical, the web server composes the message to be delivered by the Internet to the IP address corresponding to the remote client.

While it is located in the server side and its name is called web server, this program is an application system (or application in short) no matter from the perspective of the networking models or from the perspective of the operating system. That is the reason why HTTP is classified as an application protocol.

Today, there are many web server available. One popular web server is called Apache. It is used to be running on Unix or Linux platform only. Now, it is also running in Windows operating system. Nginx is another popular web server which can be running in Unix, Linux and Windows operating systems. Precisely, the features of Nginx are more than a web server. It also bundles other features in it. Microsoft has developed a web server called Internet Information Server (IIS).

## 2.2 Browser

A web browser, like Chrome or Internet Explorer, is an application system which is able to interpret an html file, formate the page layout and then display the web page on the browser window. A browser usually has the following user interface.

- Back and forward buttons.
- A reload button.
- A stop button to stop loading a page.
- An address bar to input the URL.

One should be noted that Microsoft Edge in Windows 10 operating system is not just a browser. It has been bundled a number of application systems inside. Apart from web browser, it also includes a PDF reader and others.

## 2.3 Hypertext markup language (HTML)

Hypertext markup language (HTML) is a programming language for making a web page. With reference to a report, this language can help us to format (1) the layout of a web page, (2) the title of the page, the size of a section or a subsection, (3) the font type of the characters, (4) tables to be included, (5) item listing and so on.

### 2.3.1 Program structure

The structure of an HTML program consists of two parts, the header and the body. All of them have to be embraced inside the `<html>` opening tag and the `</html>` closing tag. Below is a part of the codes for the course homepage.

```
<html>
<header>
  <title>Introduction to Computer Science</title>
  <meta http-equiv="Content-Type" content="text/html">
  <meta name="keywords" content="John Sum">
  <style type="text/css">
  body { color: black; background: #ffeedd;}
</header>
</html>
```



```

body { font-family: Garamond, "Times New Roman";}
body { margin-left: 10%; margin-right: 10%}
p { margin-top: 0.75em; margin-bottom: 0em}
</style>
</header>

<body>
  <h1>INTRODUCTION TO COMPUTER SCIENCE</h1>
  <hr>
  <h3>COURSE OBJECTIVES</H3>
  .....
  .....
  <h3>LANGUAGE OF INSTRUCTION</H3>
  .....
  .....
  <h3>PRE-REQUISITES</h3>
  .....
  .....
  <H3>COURSE CONTENTS</H3>
  .....
</body>
</html>

```

The information to be put inside the header tags include (1) the title of the page which will be displayed on the tab of the page, (2) the keywords of the page which can let the search engine to tag this paper, (3) the color of the characters and the background color, (4) the font of the character and (5) the page layout. Inside the body tags, the content to be displayed and the format of text content will be specified.

### 2.3.2 Section heading

Section headings could simply be formatted by the <H1> tags, as shown in the above program segment. Subsection headings could be formatted by the <H2> or <H3> tags. Section heading tags not just specify the font size of the text inside the tags, they also specify how much the vertical space above and the space below the heading should be reserved.

### 2.3.3 Font type and font size

In a document, some words might be in bold or italic for emphasizing the importance of those words. To do so, we can use `<b>` and `<i>` tags. Here is an example.

```
<html>
  <header>
  .....
  .....
</header>

  <body>
  <h2>About Me</h2>
  I am a <b>professor</b> in NCHU.

  I am a <i>professor</i> in NCHU.

  I am a <i><b>professor</b></i> in NCHU.

  I am a <font size="8"><b>professor</b></font>
  </body>
</html>
```

The last line, the word 'professor' will be displayed in bold face and italic.

The font size of text can be formatted by using the tags like `<small>` and `<Large>`. Moreover, font size can also be specified by using `<font>` tag, as shown on the last line of code in the `<body>`.

### 2.3.4 Listing

To list a number of items, we can use the `<ol>` or `<ul>` tag. The former tag is used for ordered listing and the latter tag is used for unordered listing. Below is an example. For the first listing, there will be listed with numbers '1', '2' and '3'. For the second listing, the items will be listed with bullets.

```
<html>
<header>
.....
.....
```

```

</header>

<body>
<h2>About Me</h2>
<ol>
<li> I am a <b>professor</b> in NCHU.
<li> I am a <i>professor</i> in NCHU.
<li> I am a <i><b>professor</b></i> in NCHU.
</ol>

<ul>
<li> I am a <b>professor</b> in NCHU.
<li> I am a <i>professor</i> in NCHU.
<li> I am a <i><b>professor</b></i> in NCHU.
</ul>

</body>
</html>

```

For advanced usage, one can also add a sub-listing (resp. sub-sub-listing) for an item (resp. an item in a sub-listing). This sub-listing (resp. sub-sub-listing) can also be ordered or unordered.

### 2.3.5 Table

<table> tag is a very useful tag. First, it can help us to add table in a web page. Second, it can be used for formatting the layout of a web page.

**Table of data:** Below is a simple example showing how data can be displayed in a table.

```

<center>
<table>
<tr> <td></td> <td>John</td> <td>Mary</td> </tr>
<tr> <td>Age</td> <td>35</td> <td>28</td> </tr>
<tr> <td>Income</td> <td>10K</td> <td>20K</td></tr>
</table>
</center>

```

The center tag is used for centering the table. This table will be displayed like the following.

	John	Mary
Age	35	28
Income	10K	20K

**Text formatting:** Below is an example showing how table tag can be used for formatting the layout of some text in the page.

```
<table>
<tr>
  <td width=100>Instructor:</td>
  <td><a href="http://web.nchu.edu.tw/~pfsum">John Sum</a>,
  <a href="http://itm.nchu.edu.tw/">ITM</a> </td>
</tr>
<tr>
  <td>Office:</td>
  <td>Room 821, CSSM Building </td>
</tr>
<tr>
  <td width>Time:</td>
  <td>Friday 09:10-12:00 </td>
</tr>
<tr>
  <td>Classroom:</td>
  <td>CS121, CSSM Building</td>
</tr>
<tr>
  <td>URL:</td>
  <td>web.nchu.edu.tw/~pfsum/CS/cs_index.html</td>
</tr>
</table>
```

This table consists of two columns and five rows. Due to the page width, I have removed the information about the email addresses. The names of the professor and his affiliation are different from the names shown in the course homepage.

On the first row, the parameter width inside the first `<td>` is to let us specify the width of the first column. This technique is not limited to the first column. The width of any column can be specified in the same manner.

### 2.3.6 Hyperlink

In the above table example, I have added two hyperlinks. One is linked to my homepage and the other is linked to the homepage of ITM.

```
<a href="http://web.nchu.edu.tw/~pfsum">John Sum</a>
<a href="http://itm.nchu.edu.tw/">ITM</a>
```

The tag for this function is called the anchor tag, `<a>`. The text to be highlighted for linking to other URL is embraced inside the tag. Here, 'John Sum' and 'ITM' are the text to be highlighted. The URL the text to be linked to is specified in the parameter 'href', namely hyperlink reference.

The anchor tag can also be used for linking other URLs, like a document, an image, a video and audio file. If those files are stored in the same directory as the web page, we can simply put the filename inside the quote of the parameter href.

```
<a href="johnface.jpg">John Sum</a>
<a href="assignment01.docx">Assignment 1</a>
<a href="assignment02.docx">Assignment 2</a>
```

For sure, one needs to upload those files to the web server. Otherwise, the page will show broken links.

### 2.3.7 Misc

HTML provides a lot more functions for advanced usages. One of them is the FORM. In my publication page, you might find that there is a text box linking to Google Scholar.

<http://web.nchu.edu.tw/~pfsum/publication.html>

Moreover, photo can also be displayed on a web page by using the tag `<img>`. Student can take a look on the web pages in my homepage for other features. For more information regarding HTML, one can search over the Internet for tutorials on HTML programming.

### 2.3.8 Editor for generating HTML program

To prepare an HTML program, there are many possible ways. As it is a program file, you can use any program editor to edit this program and then save it as an HTML file. In Windows operating system, you can use WordPad or Notepad. These editors are text editors. Notepad will automatically save the file as a text file. WordPad will not do it automatically. You need to select the file type as a text file when you are saving the HTML program.

## 2.4 Interpreter

Once an html program (e.g. index.html) has been received, the browser interprets the program line by line and then converts each line of code to the corresponding machine code for text display on the browser window. This mode of conversion is called interpretation. The program doing this is called the interpreter.

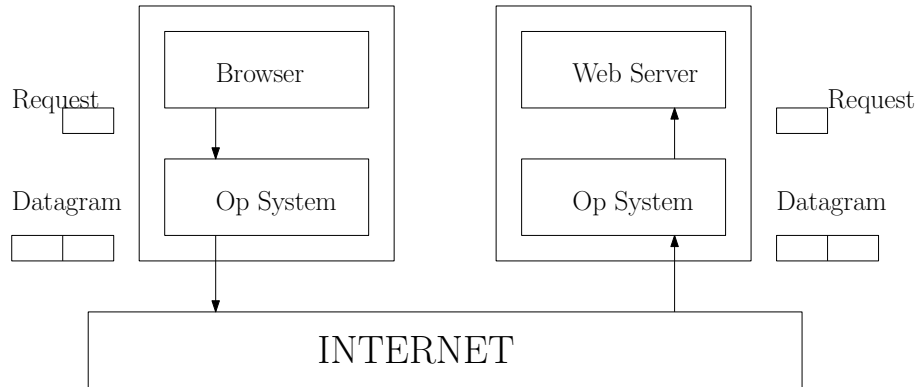
A browser must have this interpreter. If the HTML interpreter cannot convert any line of code, it could ignore the line and then proceed to convert the next line of code. For some cases, it generates machine code for displaying error message.

It should be noted that another type of converter is called compiler. It converts the entire program to an executable file. In case there is an error in a line of code, compiler will not do the conversion. Error message will thus be reported.

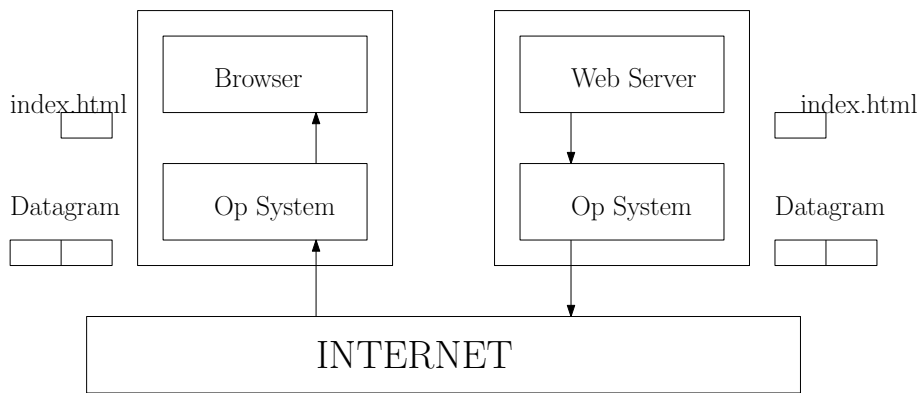
## 2.5 Web Browsing

Once all the necessary (HTML) files and the image files have been available on the web server, user could browse the web page by using the web browser. The mechanism is illustrated in Figure 2.

**Browser side:** Once a user has invoked a browser and entered the URL at the address bar, the browser creates a request message with the URL information inside and pass it to the operating system. Upon receiving the request message, the operating system creates the datagram for the message with (i) source and destination IP addresses, (ii) port number 80 (this number is assigned for HTTP applications), (iii) session ID and other relevant information. The datagram will then pass to the Internet for delivery.



(a) From browser to web server.



(b) From web server to browser.

Figure 2: Browsing a web page.

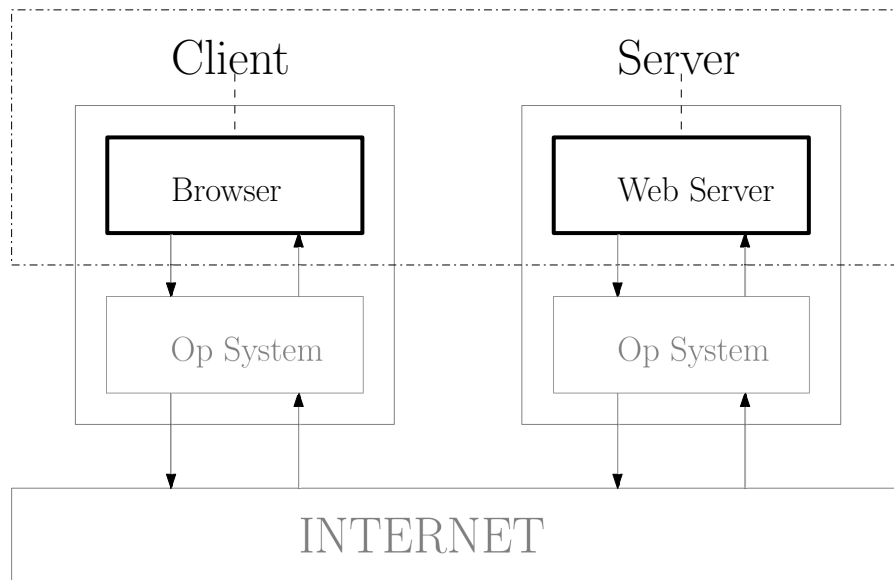


Figure 3: Client-server computing: From application-level perspective.

**Web server side:** Once the datagram has arrived the destination IP address. The operating system of the destination machine will decapsulate the datagram and pass the message to the web server. The web server checks that it is a request for a URL. The web server thus creates a reply message in which the HTML file is included and passes it to the operating system. The operating system then creates a datagram and passes it to the Internet.

**Browser side:** On the browser machine, the operating system decapsulates the datagram sent from the web server machine and passes the HTML file to the browser. The browser interprets the file and displays the contents in its window.

From application-level point of view, the interaction is also considered as client-server computing, Figure 3. Browser is the client and the web server is the server. The web server serves the browsers which request for services.



## 3 Other Internet Applications

Web browsing (or web applications) is just one simple application of the Internet. For half a century, many applications have been developed. Clearly, new applications are under development as well. It is not possible to introduce all them in this course. Here, only a few of them are introduced.

### 3.1 File transfer

File transfer is an important application. As mentioned earlier, the message (or data) encapsulated in a packet is far smaller than a file like a document or a video. A document file could be larger than one mega bytes. In such case, it is needed to chop the file into small segments. The segments are put in the packets and sent to destination IP address. Once the packets have arrived the destination machine, the machine will need to extract the file segments from the packets and reconstruct the file.

The technologies for this application is embraced in the protocol called file transfer protocol (FTP) which was initially released in 1971 and later in 1980 for TCP/IP version. The software supporting this application is called FTP server. One usage of FTP server is for archiving technical reports.

For each FTP server, there is a default account for public access. In accordance with the protocol, this account name is set to 'anonymous'. The password of this account is nothing (or empty). Let say a FTP server called `ftp.nchu.edu.tw`. It is available for public access.

```
C:\Users\John Sum>ftp ftp.nchu.edu.tw
Connected to ftp.nchu.edu.tw
220 (vsFTPd 3.0.2)
Username: anonymous
Password:
230 Login successful.
ftp>
*
*** Upload or download files ***
*
ftp>quit
C:\Users\John Sum>
```

Once the ftp prompt has been shown, you can enter commands. Again, the set of commands is defined in the protocol. In the FTP environment, you can create a directory and upload your file here. To upload a file, the command 'put' is used. To download a file, you can use the command 'get'. The set of commands can be recalled by typing 'help' on the ftp prompt.

Clearly, this manual way of ftp access is not user friendly for many users. Application systems are thus developed for this file transfer application. FileZilla is one of them<sup>3</sup>.

## 3.2 Electronic mail (Email)

Another important application on Internet is email. The protocol supporting this application is called simple mail transfer protocol (SMTP) which was introduced in 1981. Nowadays, almost all webmail systems are developed based upon this protocol. Two notable inventions in SMTP is the symbol @ and the format of an email address, like `pfsun@nchu.edu.tw`.

The characters on the left hand side of @ is the account name of the user who is able to access the SMTP server, yet another application system. The characters on the right hand side of @ is the domain name. As one domain usually has one mail server, email messages will be automatically routed to the mail server once it has arrived the machine corresponding to `nchu.edu.tw`. In NCHU, the mail server handling the emails for the teaching staff is named `dragon.nchu.edu.tw`. So, it is no different to send the email to `pfsun@nchu.edu.tw` or `pfsun@dragon.nchu.edu.tw`.

# 4 Other Communication Networks

Telephone network and Internet are just two exemplar communication networks. In reality, there are many other communication networks in the world.

## 4.1 Existing networks

Here, let us name a few.

- ATM network: Network connecting the automatic teller machines and the banking systems.

---

<sup>3</sup>URL: <https://en.wikipedia.org/wiki/FileZilla>.

- Vehicle network: Network connecting the computers in vehicles.
- Sensor network: Network connecting sensors for monitoring a specific area its temperature, humidity, PM2.5 and so on. These networks are usually applied for environmental monitoring. Some of them are deployed on land and some of them are deployed under the sea.
- Personal area network (PAN): Network connecting your cell phone and wearable devices. One application of PAN is for health care monitoring.
- Amazon GO, Google Home: Network of home appliances and the voice command interfacing device.

Each of these networks has its own communication protocol. Today, these technologies are rather mature.

Still, scientists and engineers have long time ago foreseen the increasing demand of network traffic and started to develop alternative communication networks to supplement the Internet. In recent years, Google and Facebook have also involved in developing such networks. Google launched a project called Project Loon<sup>4</sup>. Facebook launched a project called Aquila<sup>5</sup>.

## 4.2 Networks under development

For the Project Loon, big balloons are sent up to the sky. Each balloon has been equipped with a wireless communication device. Thus, the balloons are able to form big wireless communication network. On one hand, each balloon acts as a router for routing messages and connecting to some Internet base stations. On the other hand, each balloon acts as an access point for the devices on ground.

For the project Aquila, unmanned flying vehicles are deployed in the sky. Similarly, each flying vehicle is equipped with a wireless communication device. So that, it can connect to other flying vehicle to form a mobile wireless network. Again, each flying vehicle acts as a router for routing message and as an access point for the ground devices and Internet base stations.

These two networks are still under development. These projects have at least two goals. First, they could supplement the Internet by handling part of the traffic load. Second, the networks could cover the areas in which the

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<sup>4</sup>URL: [https://en.wikipedia.org/wiki/Loon\\_LLC](https://en.wikipedia.org/wiki/Loon_LLC).

<sup>5</sup>URL: [https://en.wikipedia.org/wiki/Facebook\\_Aquila](https://en.wikipedia.org/wiki/Facebook_Aquila).

existing communication networks cannot cover, like desert, mountains and sea. Currently, users in these areas can only access the telephone networks or Internet via satellites. It is way more expensive.

### **4.3 Network for outerspace communication**

For more than a decades, there have been a lot of researches on the development of outerspace communication network. Imagine that you would like to send an email from the earth to Mars. How could it be possible? Scientists and engineers are now working on it.

One approach is to let spacecrafts act as carriers and routers. At the same time, satellites are put in orbiting at every planet in the solar system. Those spacecrafts and satellites act as base stations for routing messages.

## **5 Conclusion**

In this chapter, additional concepts on computer networks have been introduced. The mechanism how an operating system manages the sessions by using process IDs is elucidated. An application of Internet, namely HTTP, has been described and how to encode a webpage by using HTML is introduced. Finally, some other Internet applications like file transfer and sending email are mentioned. Other communication networks are introduced.

To extend the coverage of the communication networks is a never-stop project. It relies on the effort of the scientists and engineers to make it real. Internet is just part of it.

## **6 Review Questions**

1. How does an operating system identify which process a message should be pass to?
2. Which system is going to create the datagram?
3. In this chapter, it has introduced two perspectives on client-server computing. What are they?
4. To make a web application work, we need at least two software. What are they?

5. The above two software have to be designed in accordance with an application protocol. What is it?
6. What is the protocols developed in the transport layer responsible for?
7. What editors can be used for creating an HTML file?
8. What is the program structure of a HTML program?
9. Describe the differences between `<ol>` and `<ul>` tags.
10. Describe the use of `<th>` in the table environment.
11. In which machine the HTML file should be uploaded?
12. The translator in the browser is an interpreter or a compiler?
13. What is the default port number of HTTP applications?
14. Describe how a file is transferred from the FTP server to the client computer.
15. Name a few existing communication networks and describe what they are used for.
16. State two goals that the projects Loon and Aquila would like to achieve.