Digital Communications Engineering 1

(COMM2108)

Introduction and Basic Concepts

Introduction

- **Lecturer**: Dr. Mark Davis
- **Room**: KE 3-025 Kevin St.
- **Email**: mark.davis@dit.ie
- **Web**: www.electronics.dit.ie/staff/mdavis

Introduction

- **Course Code:** COMM2108
- **Assessment***: 60% Exam, 40% Lab
- **Lectures:** 2 hours/week
- **Labs:** 2 hours/week

**NB - you must achieve at least 35% of total available marks in each component*

Introduction

- This module is designed to give an appreciation of the principles of digital communications engineering. After completing this module you should:

  – *Be able to identify the main elements of a digital communications system.*

  – *Understand source formatting, in particular sampling, quantisation, signal-to-quantisation noise ratio.*

  – *Be able to quantify the performance of baseband digital systems in terms of bandwidth requirements, intersymbol interference, and bit-error rates.*

Introduction

- The module content includes:
  - *Introduction and Basic Concepts*
  - *Source Formatting (Sampling, Quantisation, PCM, Companding, and Codecs)*
  - *Multiplexing (Multiplexing and multiple access schemes, FDM, TDM)*
  - *Baseband Communication (Generation, Transmission, Detection)*

Introduction

- Module Textbooks:
  - *Digital Communications: Fundamentals and Applications (2nd Edition), Bernard Sklar, Prentice Hall (2001).*
  - *Communication Systems (5th Edition), Simon Haykin and Michael Moher, Wiley (2010).*
  - *Principles of Communications Systems, Modulation, and Noise (6th Edition), Wiley, Rodger E. Ziemer and William H. Tranter (2000).*

Introduction

- The most obvious question is: *Why digital communications ?*
- More and more of our communications services (domestic, business and entertainment) are being delivered in a *digital* format.
- For example:
  - Telephony in the 1970s (modern digital PSTN)
  - CDs in the 1980s (music reproduction)
  - Mobile telephony in the 1990s (GSM phones)
  - Digital TV in 1999 (also HDTV since 2006)
  - Analogue Switch off in 24th October 2012.

Introduction

- Also new services have been introduced, most notable of these is the *Internet* which has undergone an explosive growth since 1996.
- Business - *Ecommerce* which is concerned with transacting business over the Internet.
- There are obvious concerns with *fraud* and *security* (*cryptographic* techniques have been developed to address these concerns).
- Most recently, the emergence of *mobile broadband* and *Web 2.0*

Introduction

- Electronic and in particular *digital* communication underpins the "information revolution" of the 21st century.
- Wealth is now created by how we generate, process, store, manage, and communicate *information*.
- Here *information* is used in the broadest meaning of the word and includes:
  - Text
  - Voice
  - Video
  - Multimedia
  - Network applications

Introduction

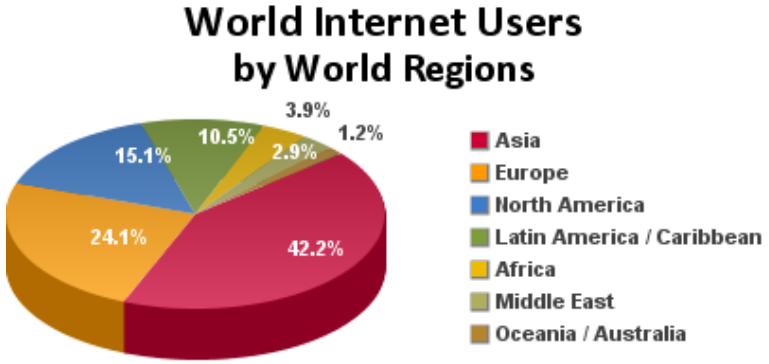
- Why the transition from analogue to digital communications?
- Cheap Hardware (flexible, complex hardware is becoming cheaper all the time, e.g. Moore's Law).
- Demand for new services (e.g. email, ecommerce, teleworking, network applications etc.)
- Control of Quality (i.e. powerful error control techniques can be employed to guarantee high quality communication).

Introduction

- Compatibility and flexibility (digital signals are easier and cheaper to store and process than analogue signals).
- Transmission (digital signals are more spectrally efficient than analogue signals which means more information can be carried in a given bandwidth).
- Security (powerful encryption techniques exist to ensure the confidentiality and integrity of the information, critical for ecommerce applications).

Introduction

- Some Internet stats (2009-2012)



Source: Internet World Stats - www.internetworldstats.com/stats.htm
1,668,870,408 Internet users for June 30, 2009
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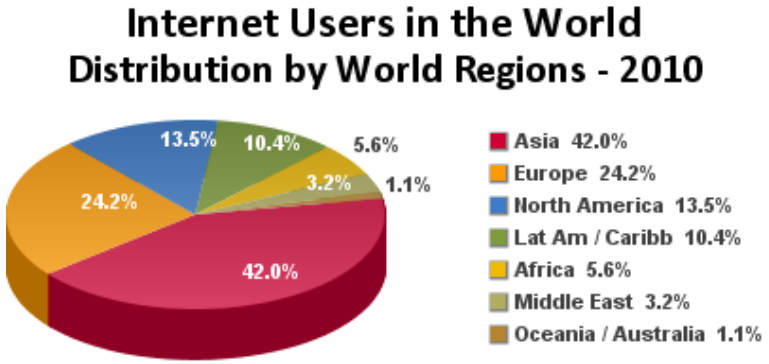

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Basis: 1,966,514,816 Internet users on June 30, 2010
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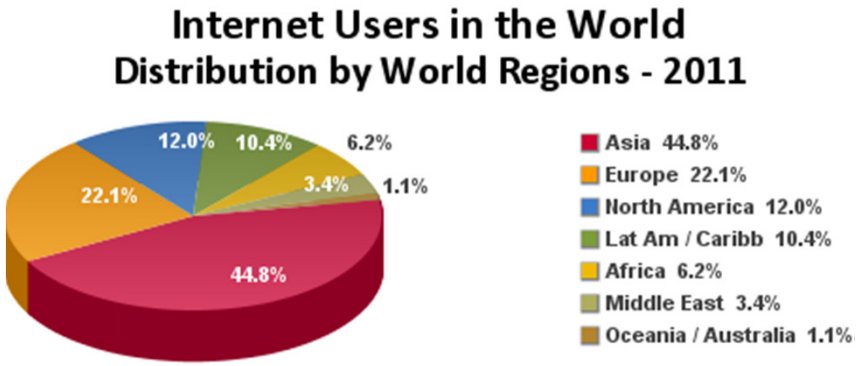

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Basis: 2,267,233,742 Internet users on December 31, 2011
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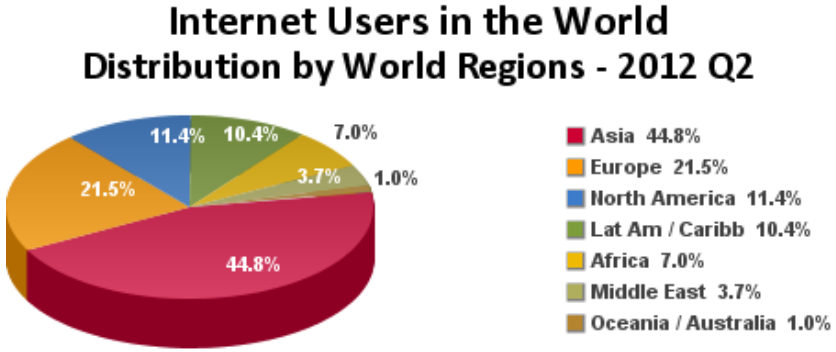

Source: Internet World Stats - www.internetworldstats.com/stats.htm
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Introduction

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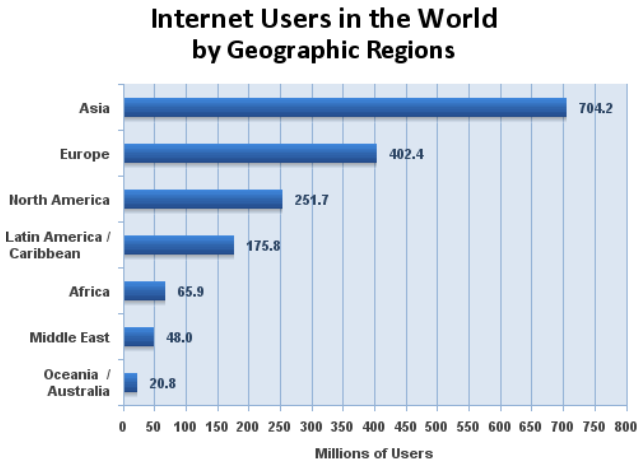

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Estimated Internet users are 1,668,870,408 for June 30, 2009
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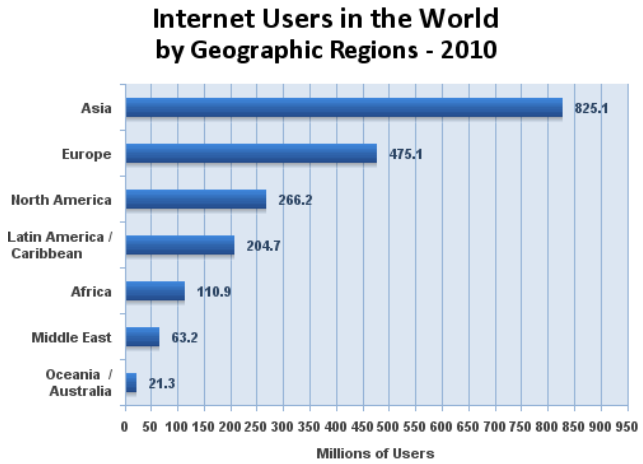

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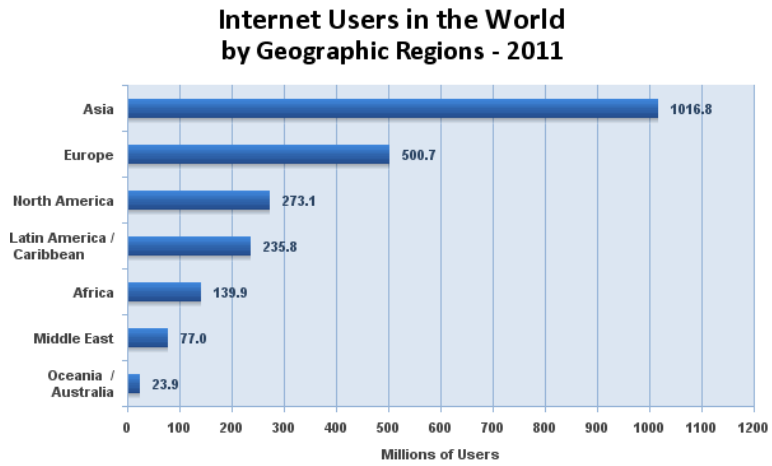

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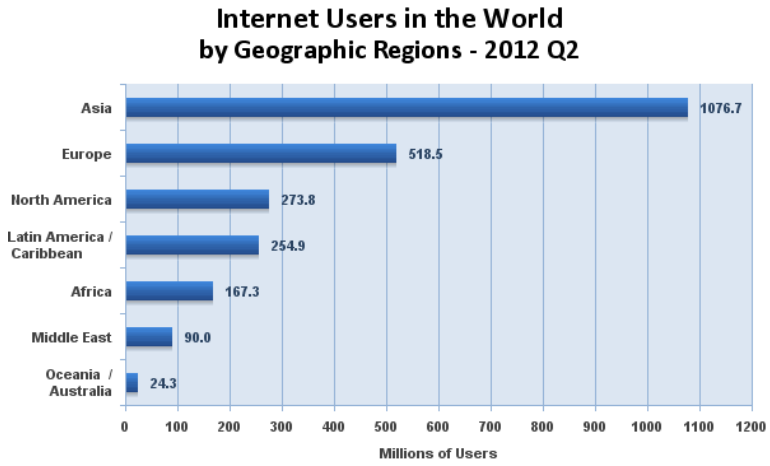

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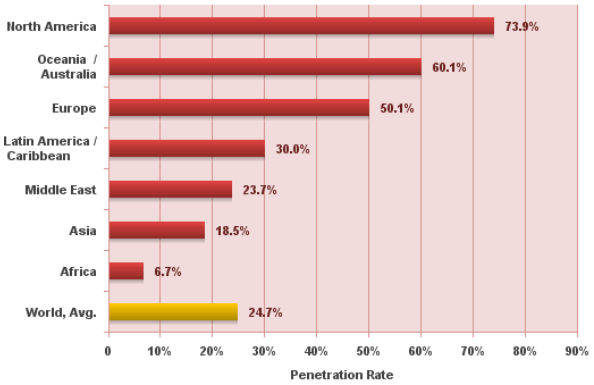
Introduction

- Some Internet stats (2009-2012)

World Internet Penetration Rates by Geographic Regions



Source: Internet World Stats - www.internetworldststs.com/stats.htm
Penetration Rates are based on a world population of 6,767,805,208 and 1,668,870,408 estimated Internet users for June 30, 2009.
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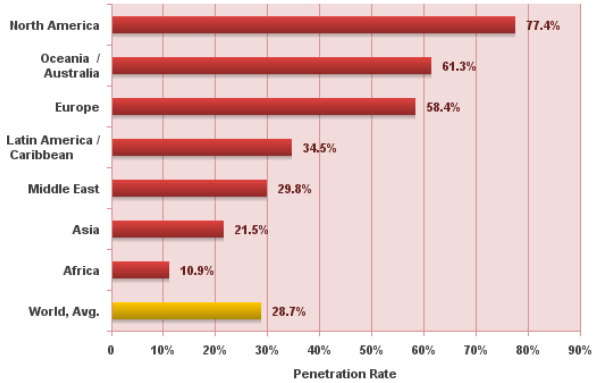
World Internet Penetration Rates by Geographic Regions - 2010



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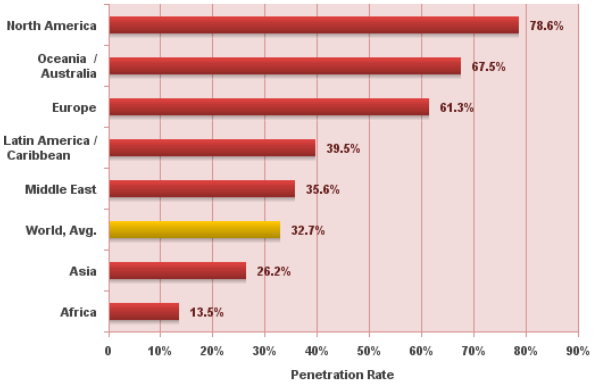
World Internet Penetration Rates by Geographic Regions - 2011



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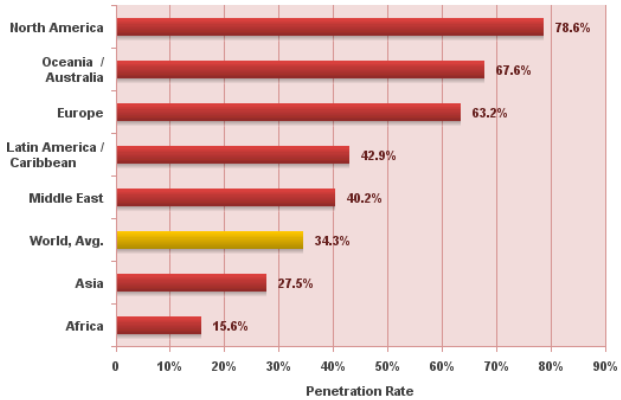
World Internet Penetration Rates by Geographic Regions - 2012 Q2



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Penetration Rates are based on a world population of 7,017,846,922 and 2,405,518,376 estimated Internet users on June 30, 2012.
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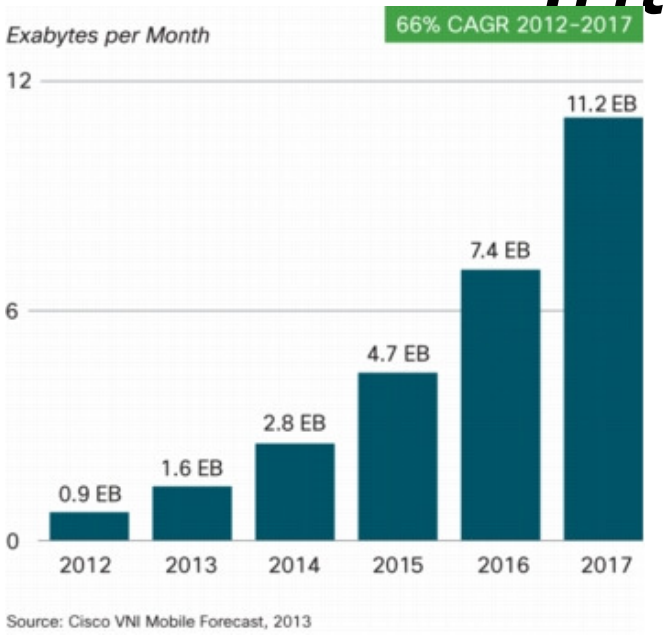
Introduction

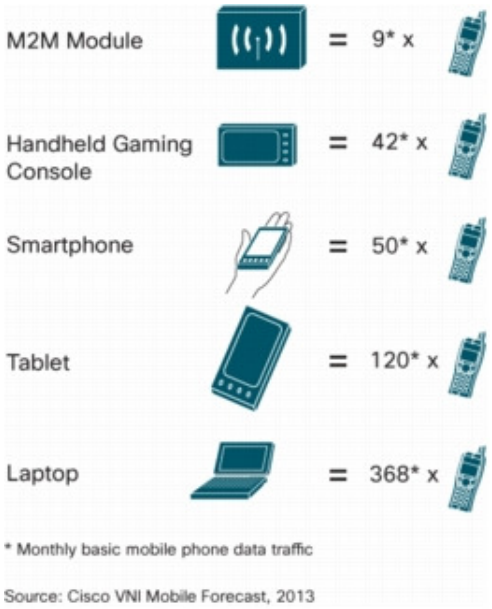
- **Biggest growth in traffic will be in mobile data traffic.**
- According to Cisco Visual Networking Index (VNI) Global Mobile Data Forecast (2012-2017), in 2011:
- **Global mobile data traffic grew 70 percent in 2012**. Global mobile data traffic reached 885 petabytes per month at the end of 2012, up from 520 petabytes per month at the end of 2011.
- **Last year's mobile data traffic was nearly twelve times the size of the entire global Internet in 2000**. Global mobile data traffic in 2012 (885 petabytes per month) was nearly twelve times greater than the total global Internet traffic in 2000 (75 petabytes per month).
- **Mobile video traffic exceeded 50 percent for the first time in 2012**. Mobile video traffic was 51 percent of traffic by the end of 2012.
- Average smartphone usage grew 81 percent in 2012. The average amount of traffic per smartphone in 2012 was 342 MB per month, up from 189 MB per month in 2011.

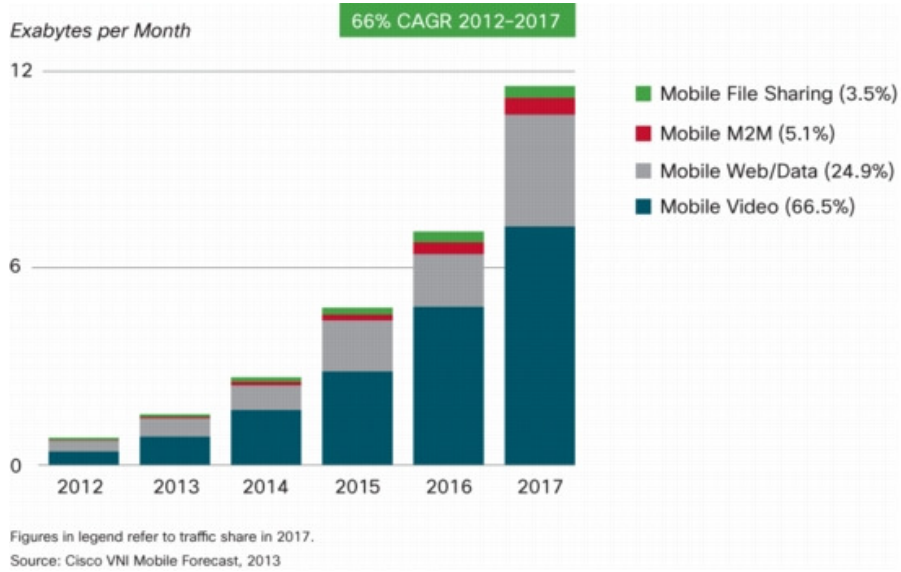
Introduction

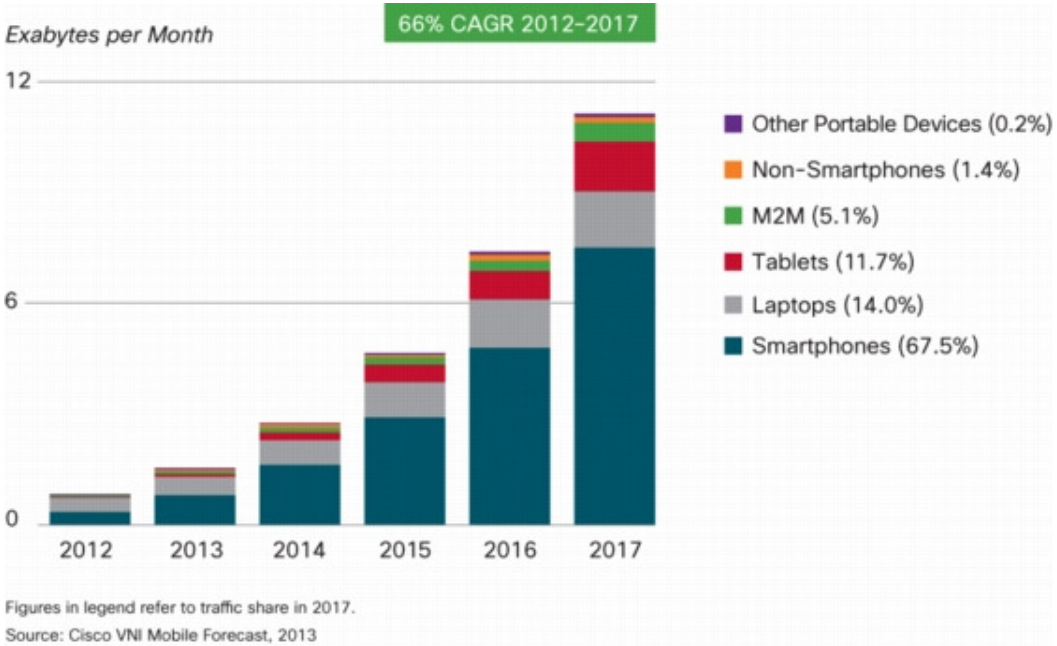
- By 2017 mobile data traffic will reach the following milestones:
  - Monthly global mobile data traffic will surpass 10 exabytes in 2017.
  - The number of mobile-connected devices will exceed the world's population in 2013.
  - The average mobile connection speed will surpass 1 Mbps in 2014.
  - Due to increased usage on smartphones, handsets will exceed 50 percent of mobile data traffic in 2013.
  - Monthly mobile tablet traffic will surpass 1 exabyte per month in 2017.
  - Tablets will exceed 10 percent of global mobile data traffic in 2015.
- Global mobile data traffic will increase 13-fold between 2012 and 2017. Mobile data traffic will grow at a compound annual growth rate (CAGR) of 66 percent from 2012 to 2017, reaching 11.2 exabytes per month by 2017.
- By the end of 2013, the number of mobile-connected devices will exceed the number of people on earth, and by 2017 there will be nearly 1.4 mobile devices per capita. There will be over 10 billion mobile-connected devices in 2017, including machine-to-machine (M2M) modules-exceeding the world's population at that time (7.6 billion).

Introduction









Introduction

- Apart from the growth of the Internet, the 1990s have witnessed a number of other significant developments taking place within the communications industry, most notably:
  - Convergence (where voice and data services are carried on the same network, e.g. VoIP and “triple play” services).
  - Deregulation (the old telecommunications monopolies have been broken up and competition has been introduced into the industry).

Introduction

- Convergence has important implications for the *telcos* (i.e. the telecommunications companies) which have traditionally catered for voice and voice-related traffic only.
- Typically telcos offered a circuit-switched channel with a bandwidth 300-3400 Hz (narrow).
- In fact, there has been over 100 years of development and investment in the circuit-switched voice network (i.e. the PSTN).
- Consequently, the modern PSTN has become a truly ubiquitous service with a very high degree of reliability and availability.

Introduction

- However, the provision of *broadband* services is now a critical part of their service offering. All of the major players offer *bundled services* combining traditional PSTN telephony with broadband access (usually over *ADSL* lines).
- Over the next 5-10 years it is predicted that IP-based (i.e. the Internet Protocol) networks will replace the traditional PSTN as the main provider of telecommunications services.
- Skype VoIP service had 663 million registered users as of Sept 2011 (over 40 million online at peak times). On 10 May 2011, Microsoft announced it had agreed to acquire Skype for $8.5 billion.

Introduction

- Deregulation has lead to the break up of the old telecommunications monopolies which were usually state owned.
- The first steps in the deregulation of the communications industry began in the USA where in 1984 the US government broke up the Bell telephone company into 22 independent Bell Operating Companies (BOCs) known as “baby bells”.
- The intention was to encourage competition, drive down costs to the consumer, and to encourage investment and development.

Introduction

- In Europe, the EU Commission forced member states to deregulate their telecommunications marketplaces on 1st January 1997.
- Originally Ireland had a derogation for 3 years, but introduced deregulation in December 1998.
- The Commission for Communciations Regulation (ComReg) is the statutory agency that oversees all aspects of the telecommunications industry in Ireland (www.comreg.ie).

Commission for
Communications Regulation

Introduction

- Deregulation has lead to modern business practices being introduced into the telecommunications industry, these include:
  - Competition
  - Acquisitions
  - Mergers
  - Floatations/IPOs (Initial Public Offering)
  - Strategic alliances

Basic Concepts

- *Signals* are the manifestations of messages exchanged at a distance.
- The generation, transmission and detection of *signals* are fundamental tasks performed by any communications system (applies to both digital and analogue signals).
- Signals can be dealt with in terms of variations of the value of some quantity with time.

Basic Concepts

- *Analogue* signals are continuous signals where changes in value occur smoothly and the rate of change is finite. Analogue signals are the natural forms of signals generated by many physical processes.
- *Discrete* signals are non-continuous signals whose values form a discrete set and occur at isolated points in the time continuum.
- *Digital* signals can assume only a limited set of values. Changes in signal value are instantaneous and the rate of change at that instant is infinite. The most common class of digital signals are *binary* signals where at any given instant of time, the signal can have one of only two possible values.

Basic Concepts

- Signals may be classified by their degree of *certainty*:
- *Deterministic* signals where at every instant the value can be related to values at neighbouring times in a way that can be expressed exactly, i.e. deterministic signals can be described by classical mathematical functions.

Basic Concepts

- *Probabilistic* signals where future values can be described only in statistical terms. Future values are estimated on the basis of the statistics associated with past values and the assumption that the behaviour will remain the same in the future.
- *Random* signals are an important subclass of probabilistic functions whose values are limited to a given range.

Basic Concepts

- Signals may be classified in terms of their *duration*:
- *Transient* signals are signals that exist for a limited period of time only. They represent the class of real-world signals that are turned on and turned off. If the signal is deterministic it can be analysed using *Fourier Transforms*.

Basic Concepts

- *Infinite* (or *eternal*) signals are signals that exist for all time. These are used to represent communication systems that are operating in steady-state.
- *Periodic* signals are an important subclass of infinite signals whose values repeat at regular intervals. Periodic signals can be analysed using *Fourier Series*.

Basic Concepts

- With a few exceptions, the signals found in real-world communications are *probabilistic* signals.
- They cannot be represented accurately by probabilistic transient or periodic functions.
- Future signal values are estimated on the basis of the statistics associated with known past values (i.e. *measurements*) and the assumption that the statistical behaviour will remain unchanged (important property known as *stationarity*).

Basic Concepts

- There are two approaches used to represent signals:
- *Time Domain* representation where the signal values are given as a function of time.
- *Frequency Domain* representation where the signal values are given as function of frequency.

Basic Concepts

- The piece of laboratory test equipment used to analyse signals in the time domain is an *oscilloscope*.
- In the frequency domain, the corresponding piece of laboratory test equipment is a *spectrum analyser* which displays the spectrum or frequency components of a signal.

Basic Concepts

- Some obvious questions regarding the use of the time domain and frequency domain representations might be:
- Which representation is the more accurate?
- Which representation is the more valid?
- Which representation is the more complete?

Basic Concepts

- The answer is simple, **neither** representation is more accurate, more valid, or more complete than the other.
- They are just two different ways of looking at the same thing.
- Usually it is a matter of convenience which will determine which representation to use.
- In general, though not always, the frequency domain representation is the more useful for communications engineering.

Basic Concepts

- Mathematical techniques have been developed to enable engineers to move back and forth between the two domains.
- These techniques come under the general heading of *Fourier techniques* after the 19th century French mathematician *Joseph Fourier (1768-1830)* who developed them.

Basic Concepts

- Two of these techniques are of particular interest to communications engineers:
- The *Fourier Series* which is used to obtain the spectrum of a periodic signal.
- The *Fourier Transform* which is used to obtain the spectrum of a non-periodic signal (and vice versa).

Basic Concepts

- One of the most important uses of the frequency domain representation is that it indicates the *bandwidth* of a signal, i.e. the range of frequencies occupied by the signal energy.
- For example:
  - The range of frequencies occupied by the human voice is approximately 300-3400 Hz resulting in a bandwidth of 3 kHz approx.
  - Music occupies a range of frequencies roughly between 30 and 15,000 Hz resulting in a bandwidth of 15 kHz approx.
  - By contrast, an analogue TV picture has a bandwidth of 6 MHz.

Basic Concepts

- The *passband* of a communications system is the range of frequencies that can be transmitted without distortion.
- To avoid distortion the passband should always be greater than the signal bandwidth.
- For example, consider what would happed if we had a communications system with a passband of 10 kHz and we attempted to transmit human voice, music and TV signals.

Basic Concepts

- For *voice* signals, the passband is much greater than the signal bandwidth and therefore the system would perform well.
- For *music* signals, only those frequencies below 10 kHz would be transmitted which will result in distortion being introduced. The degree of distortion would very much depend on the type of music but generally it would not be too severe.
- For *TV* signals where the passband is very much less than the signal bandwidth, severe distortion would be introduced.

Basic Concepts

- Digital communications is simply the practice of exchanging information by using *finite* sets of signals.
- In practice these signals are in the form of electrical waveforms (e.g. pulses) or electromagnetic fields (e.g. radio waves).
- The five basic elements of any communications system are:
  - Information Source
  - Transmitter
  - Communications Channel
  - Receiver
  - Information Sink

Basic Concepts

- The information source represents the *message* or the information to be communicated.
- The message or information can have many forms, it can be human speech, video, text, or digital data from a PC/server.
- The signal produced by the source is often referred to as the *baseband* signal.
- Generally the information or baseband signal needs to be *formatted* (or *coded*) into a digital format.

Basic Concepts

- The function of the *transmitter* is to convert the baseband signal into a form that is compatible with the communications channel.
- The *communications channel* is the medium over which the communication takes place (e.g. coaxial cable, optical fibre, or radio waves).
- The function of the *receiver* is to recover the original baseband signal from the communications channel.

Basic Concepts

- Digital communications (at least at the physical layer) is all about *coding*.
- The main functions of coding are:
  - *Source representation* which is concerned with the accurate and efficient representation of information.
  - *Error control* which is concerned with protection information against transmission errors.
  - *Security* which is concerned with ensuring the confidentiality and integrity of information through the use of cryptographic techniques.

Basic Concepts – Summary

- Digital communications is:
  - simply the practice of exchanging information by using *finite* sets of signals.
  - is all about *coding* (at least at the physical layer).
  - is concerned with answering the question
    - *<u>Which</u> signal was transmitted?*