CSCU9A1: Systems 4
Systems to networks

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Content

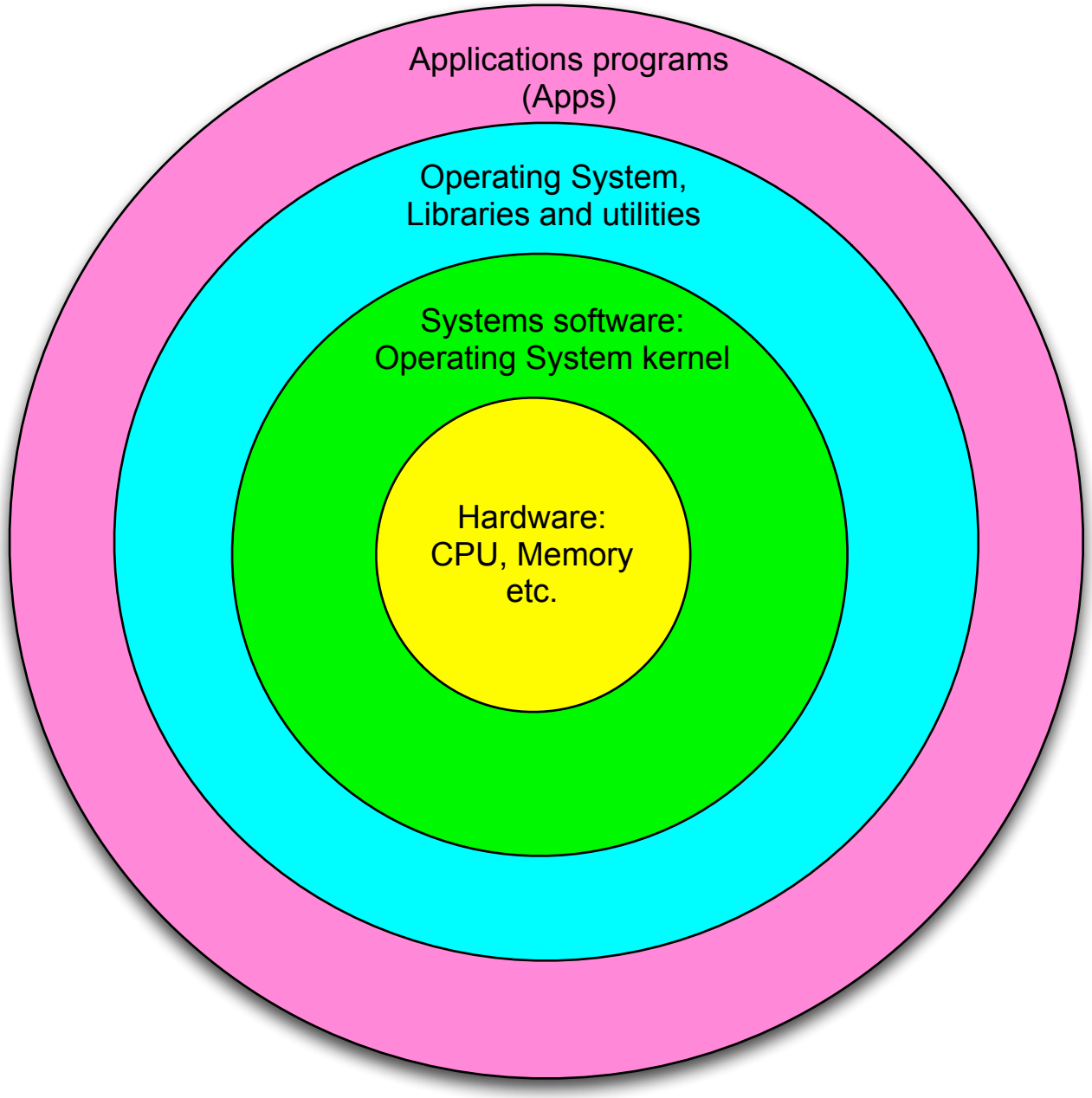
- Software architecture (very brief)
- What *are* networks? (specifically computer networks)
  - Including a little theory
- What are they used for?
- Network classes
- Internet and its growth
- How do they work? (next lecture)

Software architecture

Layered software architecture:

Enables separation of types of software

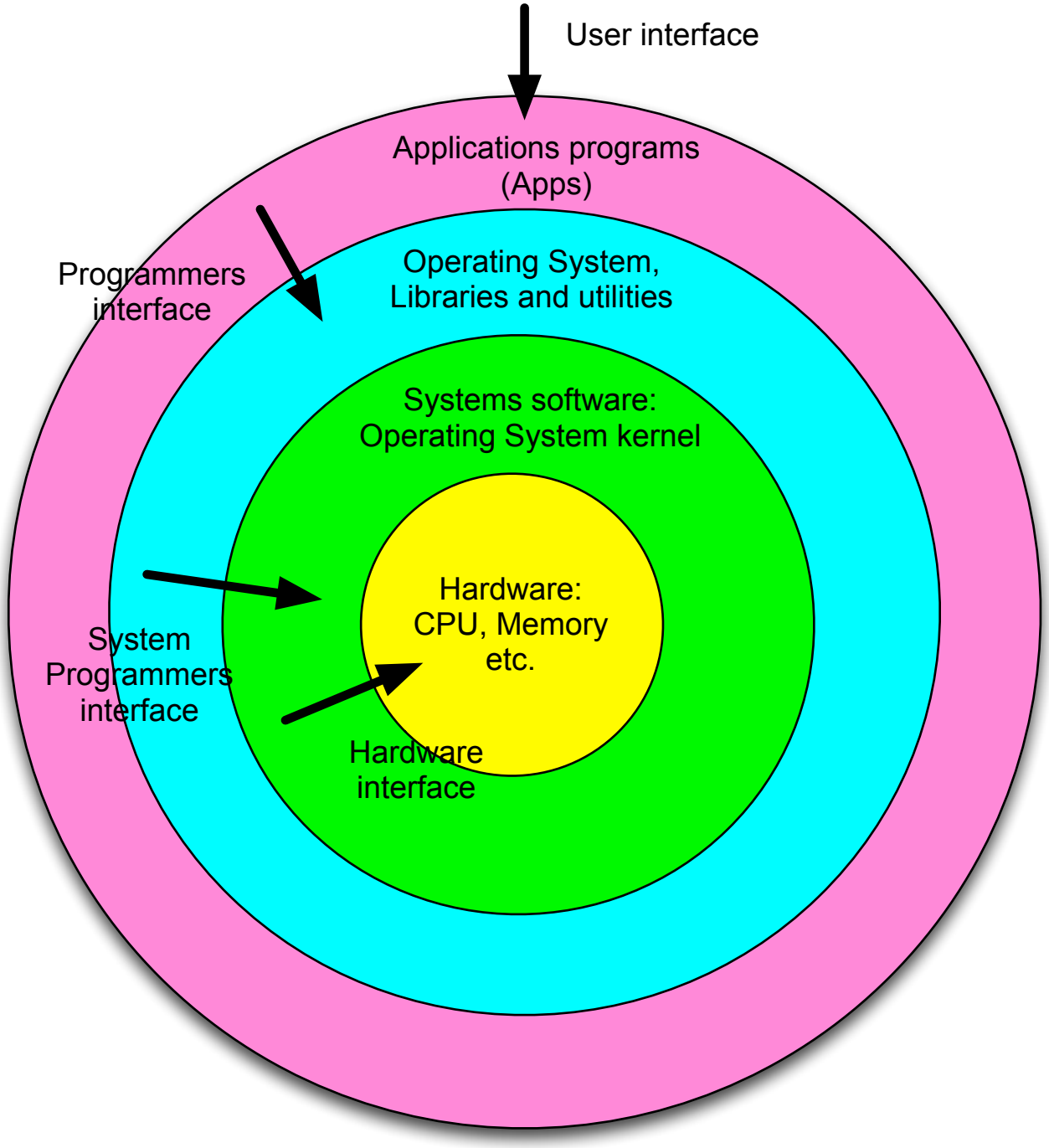
Outer layers use only the facilities of the next layer in.



Interaction types

Normal users see only the Application program interface

(The OS has an outermost user interface level, which is essentially like an application)



Programming interfaces

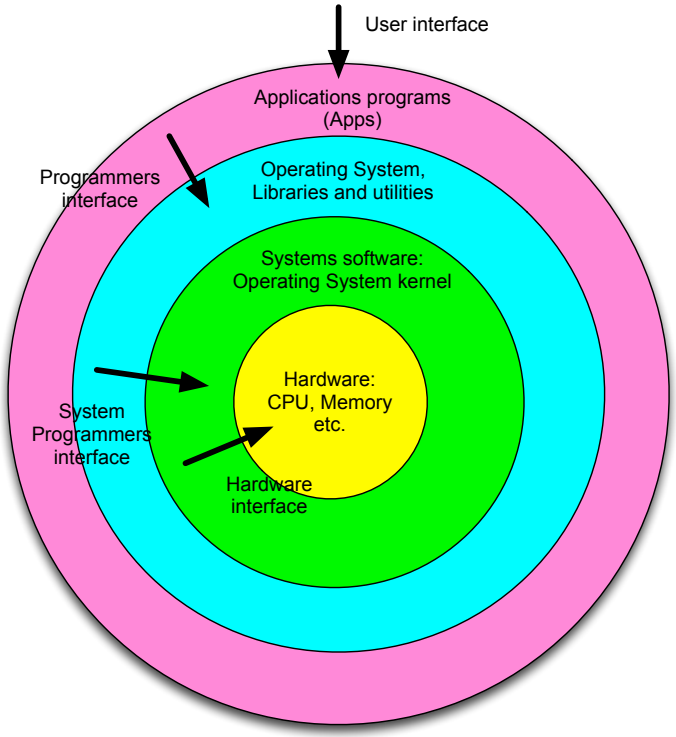
Programmers come in different varieties

Applications programmers see the Programmers interface

- They use the facilities provided by the OS, and the libraries and utilities that come with it

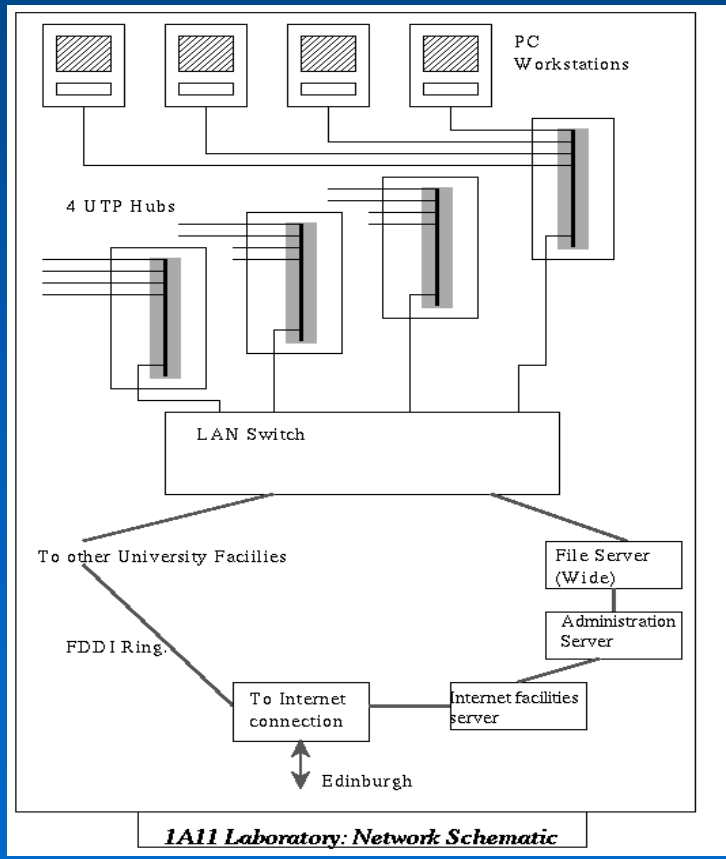
Systems programmers often interact with lower level aspects of the operating system

The hardware interface is used by those writing the kernel. (generally, they write a micro-kernel first, and use its capabilities!)



Systems & Networks

- So far we have looked at systems as it pertains to single computers
  - Stand-alone machines
- But most desktop, laptop, and smart-phone computers are networked
  - Each machine is part of something larger
    - Enabling sharing of data, sharing of equipment
    - Creation of a *distributed computer system*



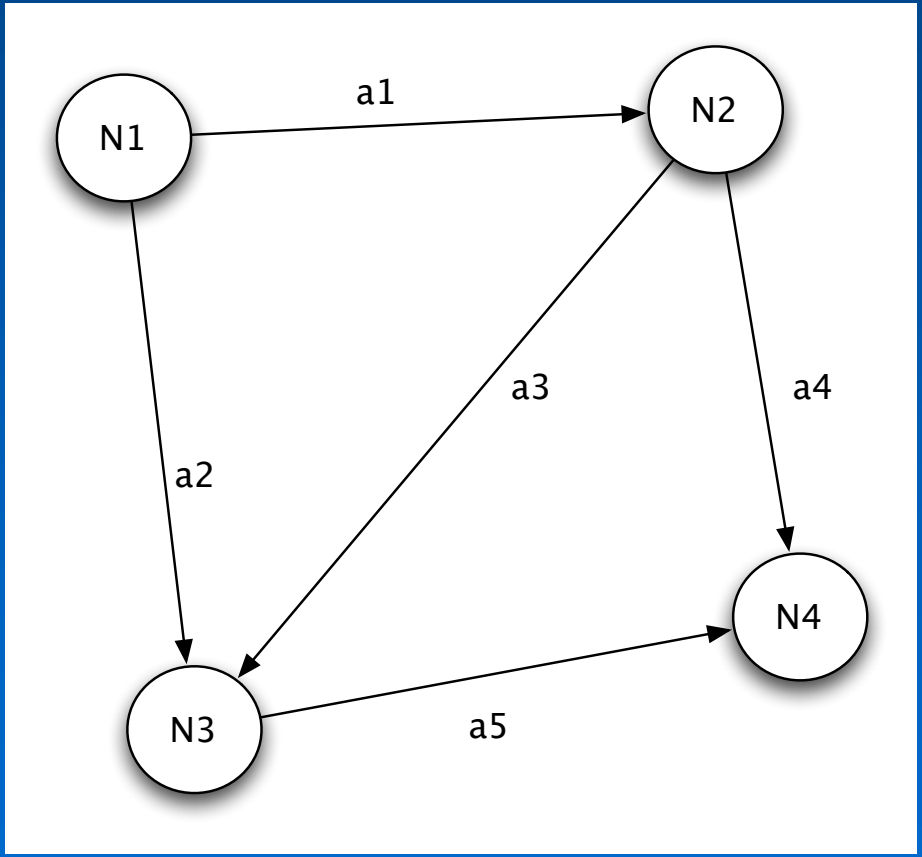
A little theory: a mathematical network (or graph)

Network consists of ***nodes***, N, and ***arcs***, A.

N = {N1, N2, N3, N4}
A = {a1, a2, a3, a4, a5}
a1 = <N1, N2>
a2 = <N1, N3>
a3 = <N2, N3>
a4 = <N2, N4>
a5 = <N3, N4>

- Note that
- Arcs are directed
  - possible to have networks with undirected arcs
- Arcs may join a node to itself

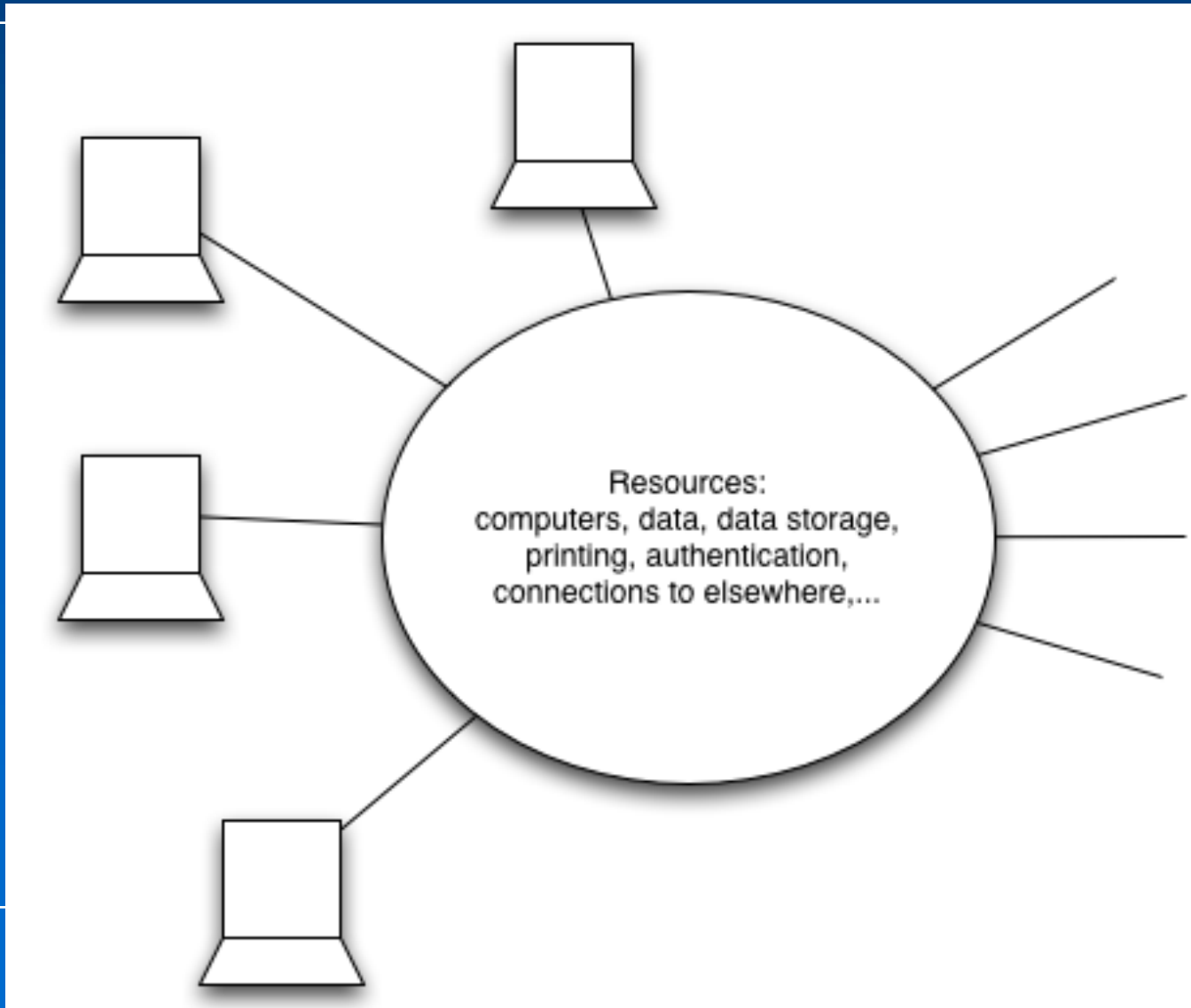
  a14 = <N7, N7>



Abstract networks

- Abstract networks or graphs are useful
  - As a theoretical underpinning
  - Allowing reasoning, or proofs to be carried out
- Nothing is *actually* made up of abstract nodes and arcs
  - But many things may be usefully considered this way
  - Rail networks, road networks, flight connections, syntax trees, networks of friends on Facebook or followers on Twitter, …
  - … and computer networks as well.

Users view of a network



Or perhaps (more likely)…

- The user sits at a machine, and is simply not aware that the machine is actually just the terminal node of a large network.
- In fact, for the non-technical user this is *exactly* what is wanted.
- But how does it get to be like this?

And another view of a network

- Smartphones
  - Are also computers
  - And are also endpoints of networks
    - Often two networks simultaneously:
    - mobile phone networks and wireless computer network

What are computer networks used for?

- The obvious:
  - Sending/receiving email
  - Browsing the web
- Actually this is only a very small part of what networks are used for
  - Although to the end user it's absolutely critical

What are computer networks used for?

- Resource sharing
- When you sit down at a machine in 2A15 (or 1A11 or …) what resources are you actually using?
  - Clearly, the keyboard, mouse and screen in front of you
  - And you are probably running processes on the CPU & Memory of the machine you are sitting at
  - But
    - Where were your username and password authenticated?
    - Where are the files you are working with?
    - When you print something, where will your printing allocation be updated?
- Plus sharing other types of resources
  - Internet connections (i.e. physical links)
  - Scanners, high-speed printers, …

Views of networks

- **At one level:**

A set of computers which communicate with each other across links that carry data

  - The computers are the nodes
  - The links are the arcs

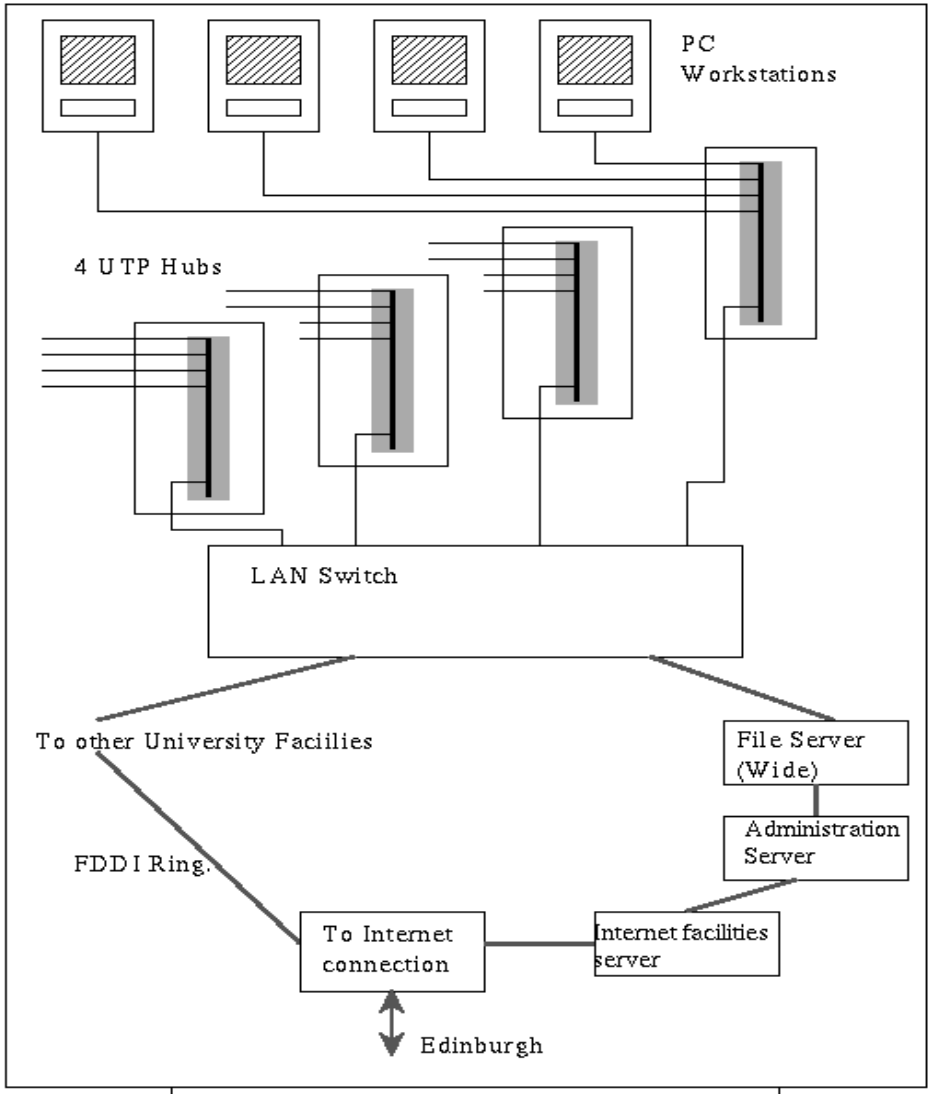
- **At a different level:**
  - A set of computers which can share resources
    - Sharing resources uses the link-based communication.
  - so that the programs communicate with other programs
    - (which also allows users, or programs users are running, to communicate with each other)
- Resource sharing is built on top of the (low-level) communicating set of computers

Distributed computers

- Often local area networks are used to create distributed computers
- Each terminal node
  - (i.e. machine the user sits at)
- Uses ***services*** provided by some of the other nodes
  - File server, authentication server, printer server, …
- So that the overall effect is that the complete network works as a single machine
  - But the user does not need to think about it at all.
  - Uniform view of the network from any terminal node.

Low-level view: the physical network

- Local area networks (LANs)
  - Ethernet, for example
- Metropolitan area networks (MANs)
  - EaSTMAN for example
- Wide area networks (WANs).
  - JANET for example

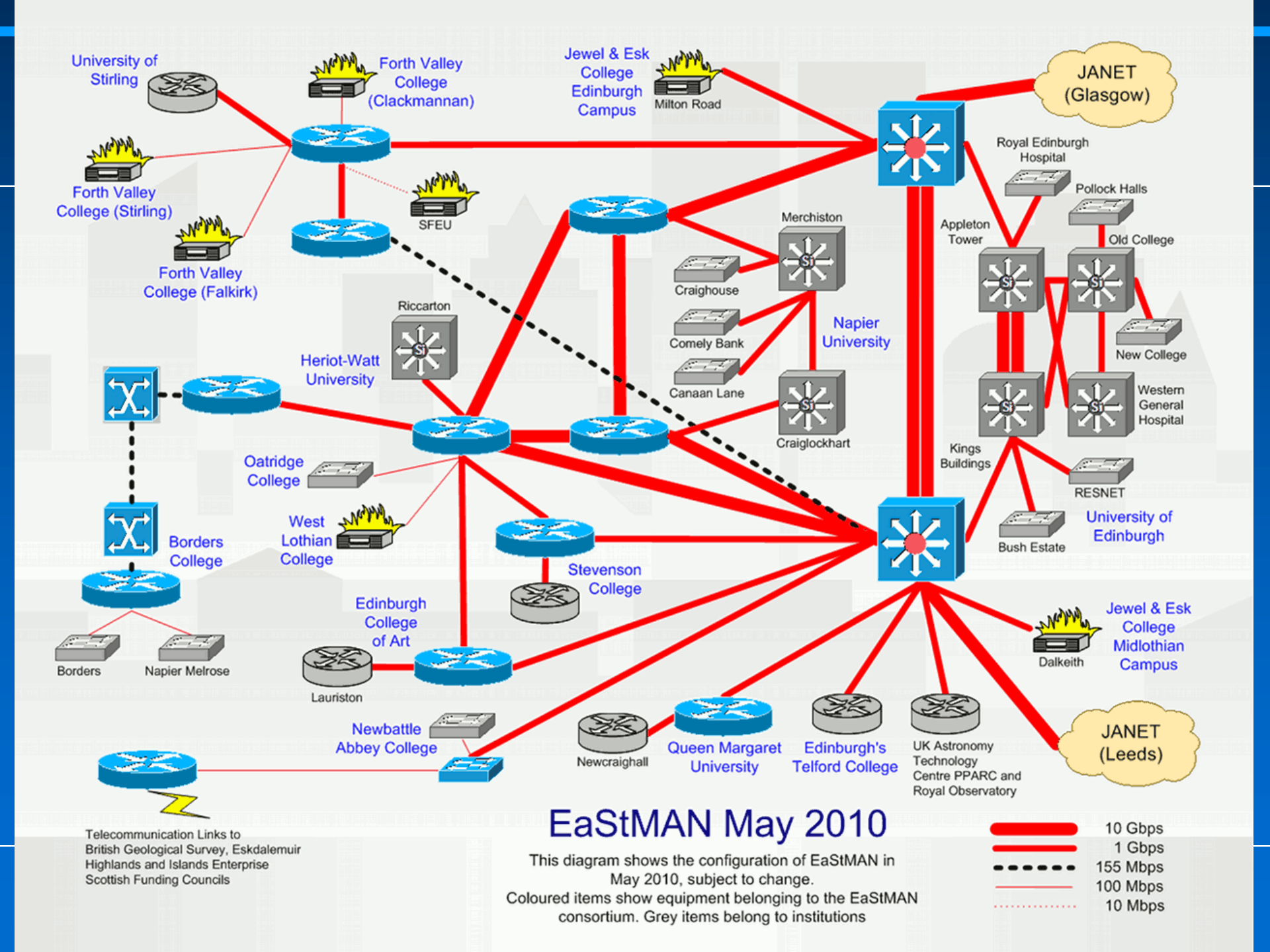


1A11 Laboratory: Network Schematic

Larger scale: metropolitan area networks

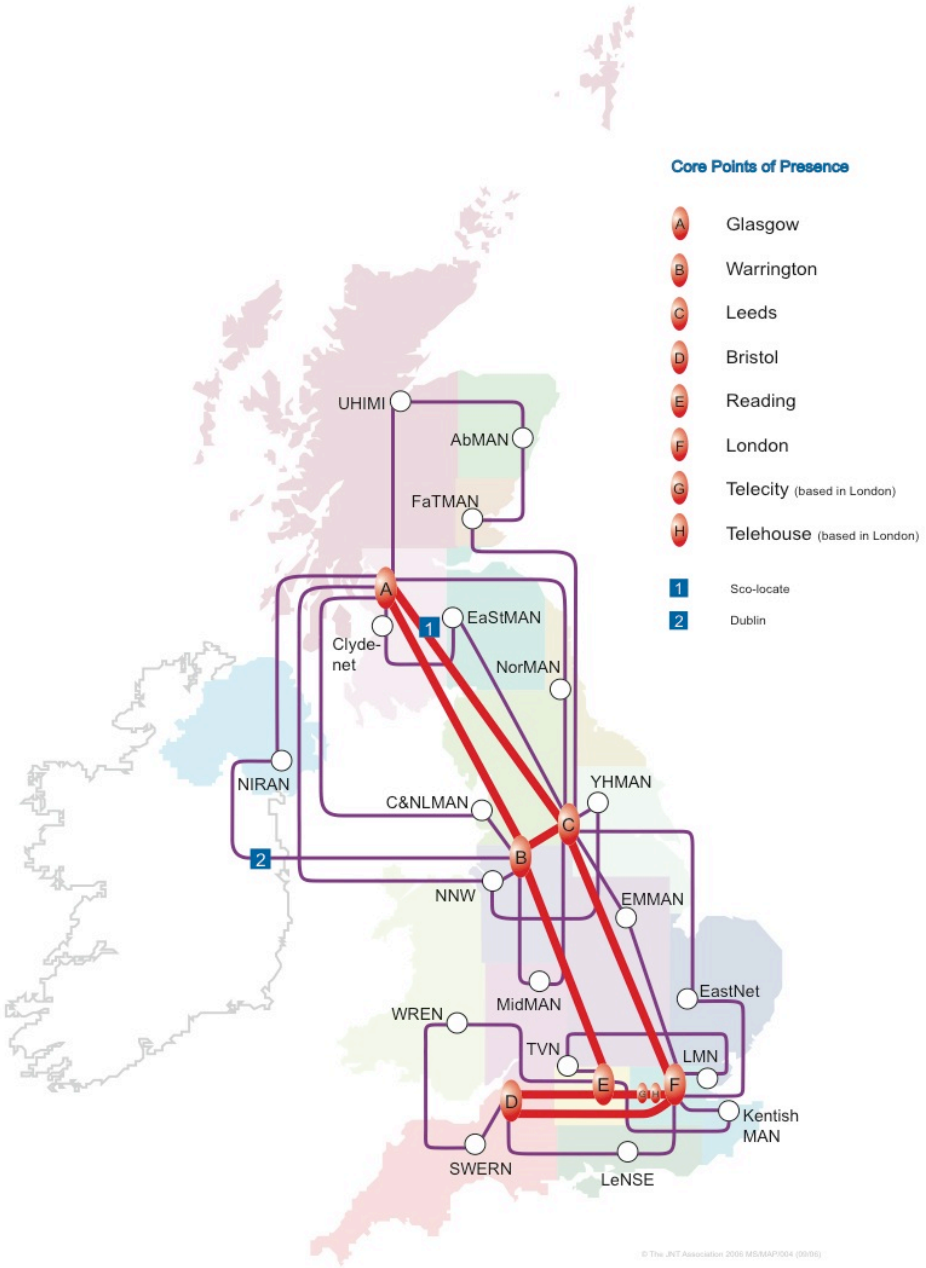
- EaSTMaN

- See
- https://netsight.ja.net/Public/TrafficLights.aspx?PageId=421


University of Stirling
Forth Valley College (Clackmannan)
Jewel & Esk College Edinburgh Campus
Milton Road
JANET (Glasgow)
Forth Valley College (Stirling)
SFEU
Forth Valley College (Falkirk)
Royal Edinburgh Hospital
Pollock Halls
Appleton Tower
Old College
Merchiston
Craighouse
Comely Bank
Canaan Lane
Napier University
Craiglockhart
New College
Riccarton
Heriot-Watt University
Western General Hospital
Kings Buildings
RESNET
Oatridge College
University of Edinburgh
Bush Estate
West Lothian College
Borders College
Stevenson College
Edinburgh College of Art
Jewel & Esk College Midlothian Campus
Dalkeith
Borders
Napier Melrose
Lauriston
Newbattle Abbey College
Newcraighall
Queen Margaret University
Edinburgh's Telford College
UK Astronomy Technology Centre PPARC and Royal Observatory
JANET (Leeds)
Telecommunication Links to
British Geological Survey, Eskdalemuir
Highlands and Islands Enterprise
Scottish Funding Councils
EaStMAN May 2010
This diagram shows the configuration of EaStMAN in May 2010, subject to change.
Coloured items show equipment belonging to the EaStMAN consortium. Grey items belong to institutions
10 Gbps
1 Gbps
155 Mbps
100 Mbps
10 Mbps

SuperJANET topology

–Backbone is up to 100Gbit/s
–Most Universities connected at at least 1Gbit/s



Fibre optic backbone

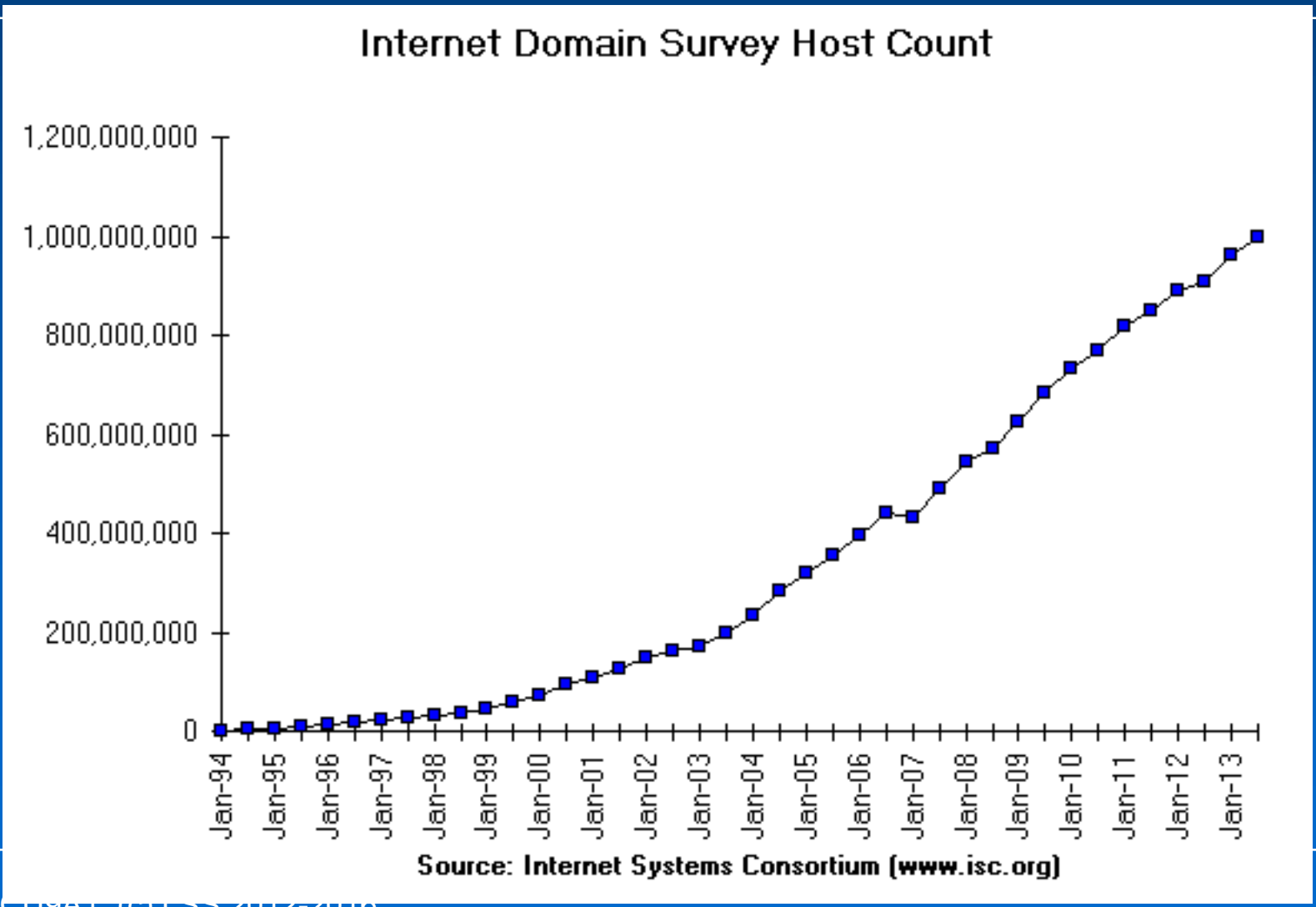
The Internet

- The Internet is a network of networks
- Started as a US Military network for communications in the late 1960's / early 1970s – the ARPANET: a cold war spin-off
  - history: see http://www.isoc.org/internet/history/
  - The novel concept was **packet switching** (of which more later)
  - The original aim of packet switching was robustness in the face of damage
    - maintaining connectivity for military communications in the event of nuclear war
  - The internet is very robust against failures
- NB: the WWW is one *service* that runs on the internet
  - There are lots of others too.

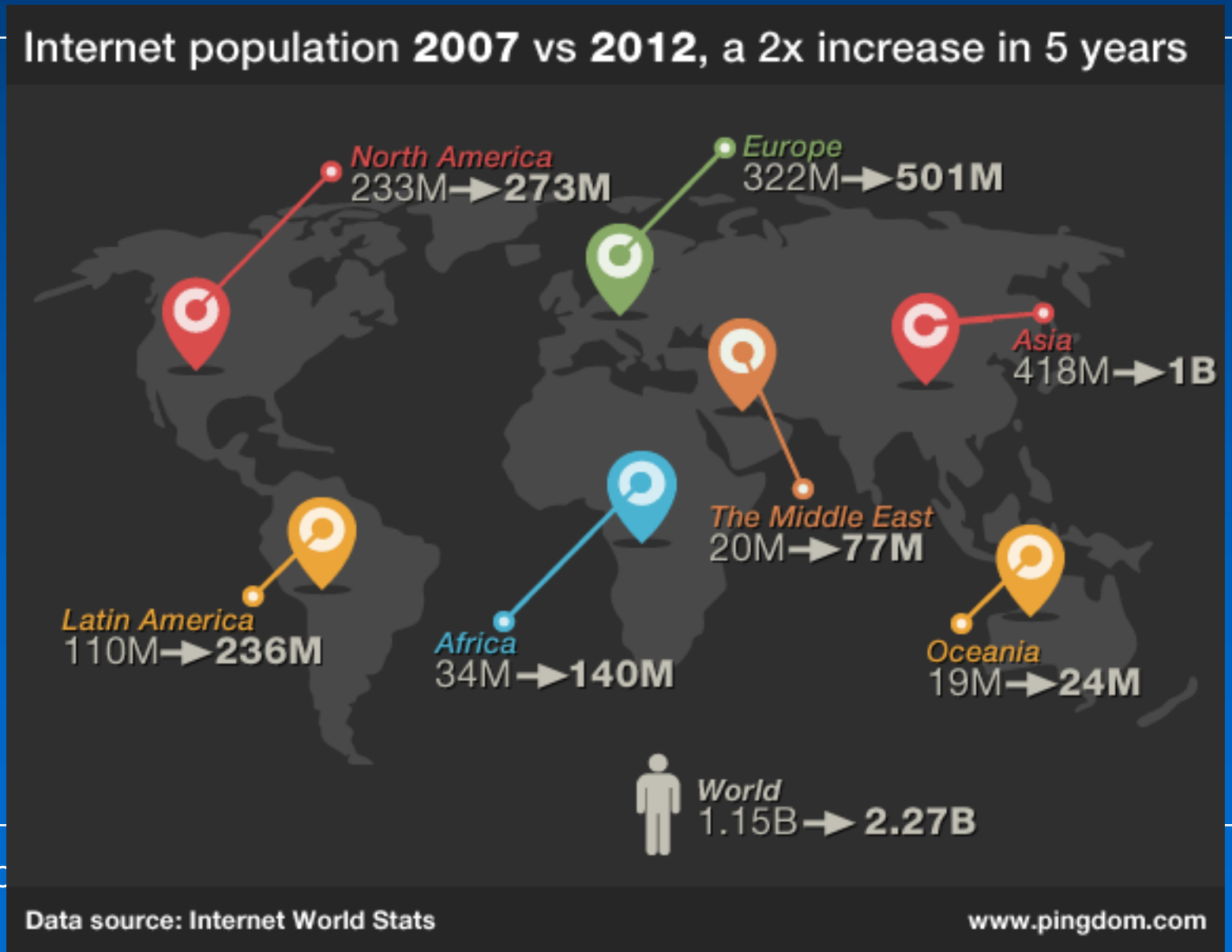
Internet Growth Trends (as in 2002)

- 1977: 111 hosts on Internet
- 1981: 213 hosts
- 1983: 562 hosts
- 1984: 1,000 hosts
- 1986: 5,000 hosts
- 1987: 10,000 hosts
- 1989: 100,000 hosts
- 1992: 1,000,000 hosts
- 2001: 150 – 175 million hosts
- 2002: over 200 million hosts

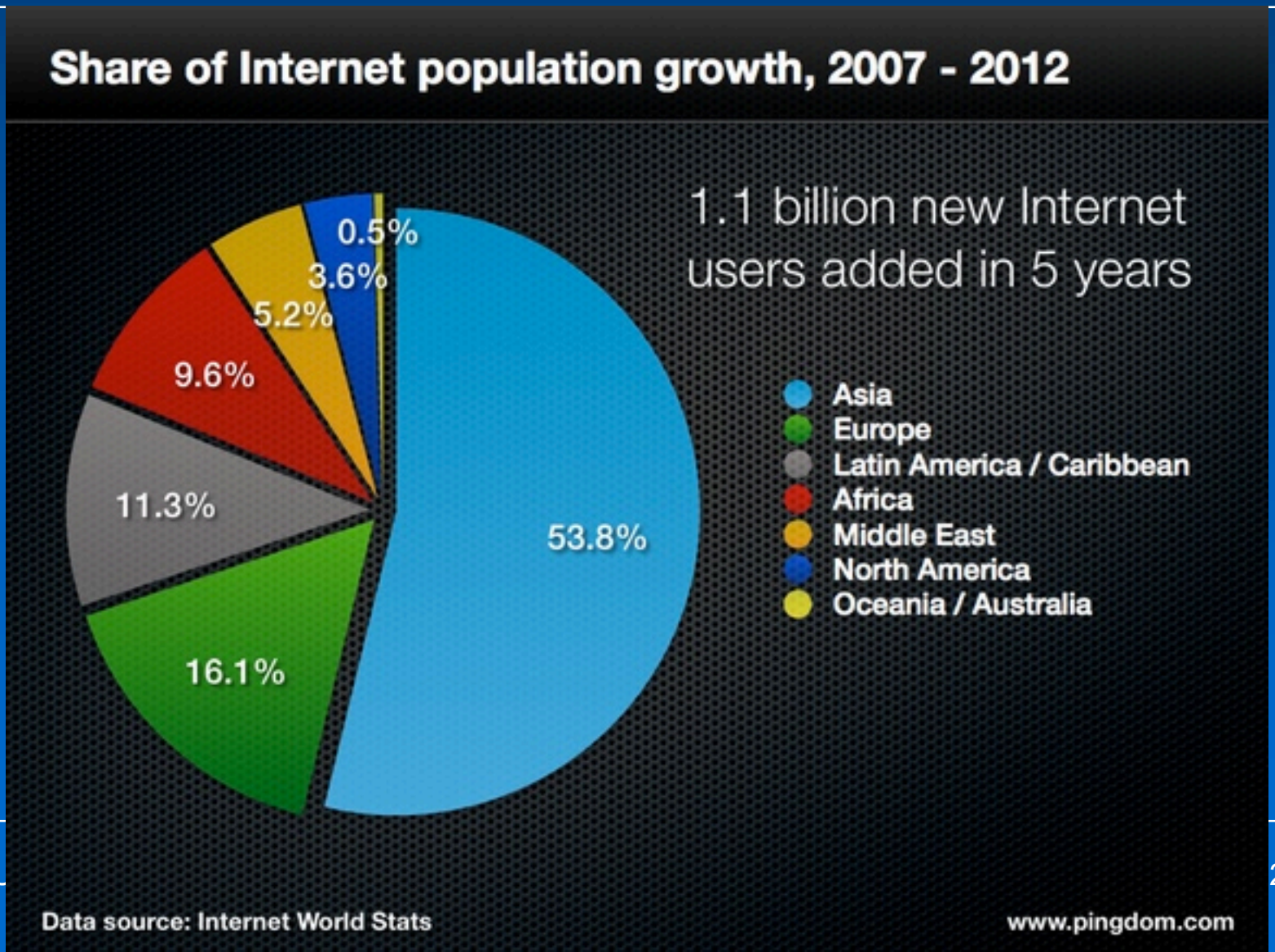
More recent information…



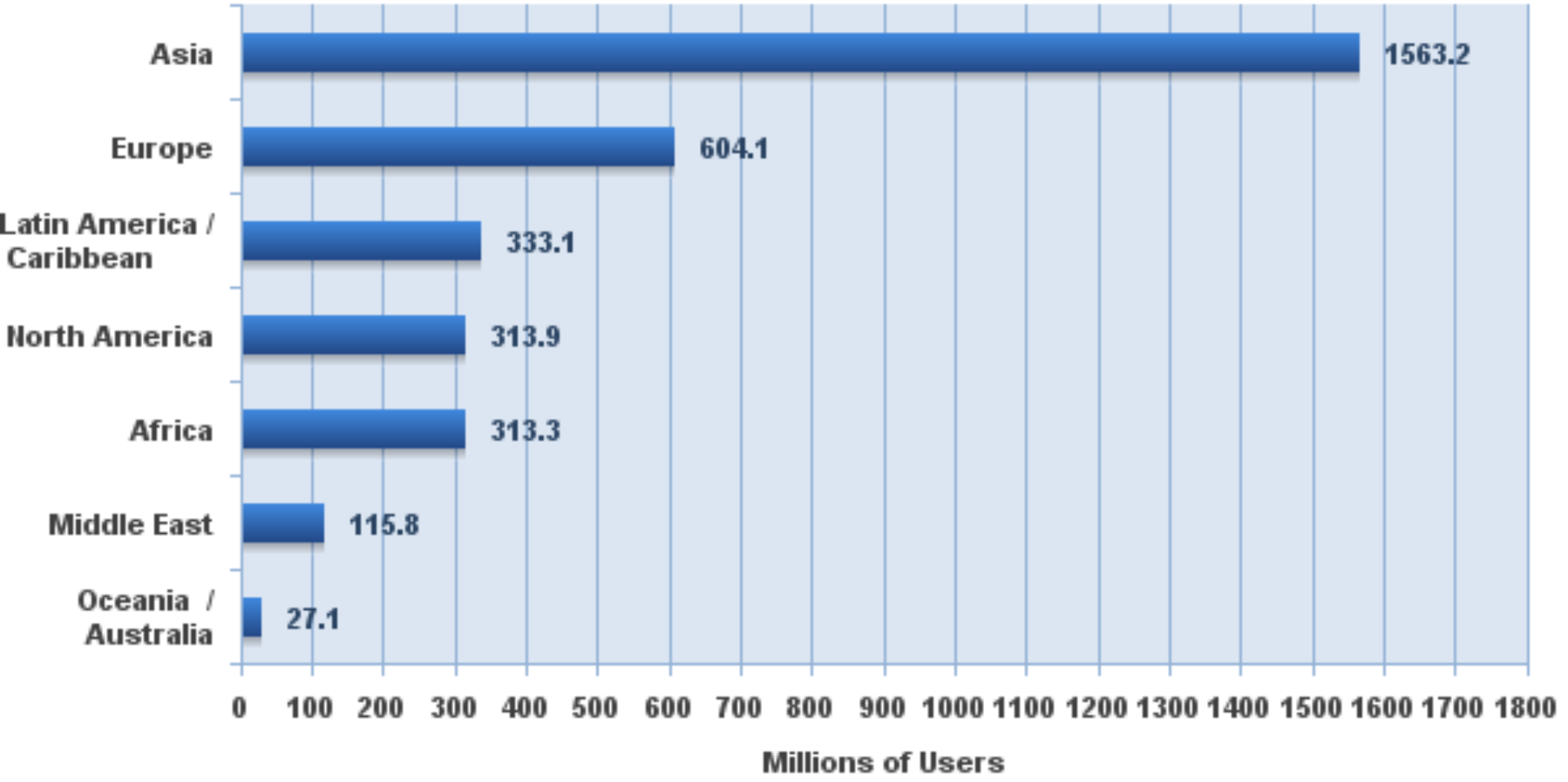
Internet growth (1)



Internet growth (2)

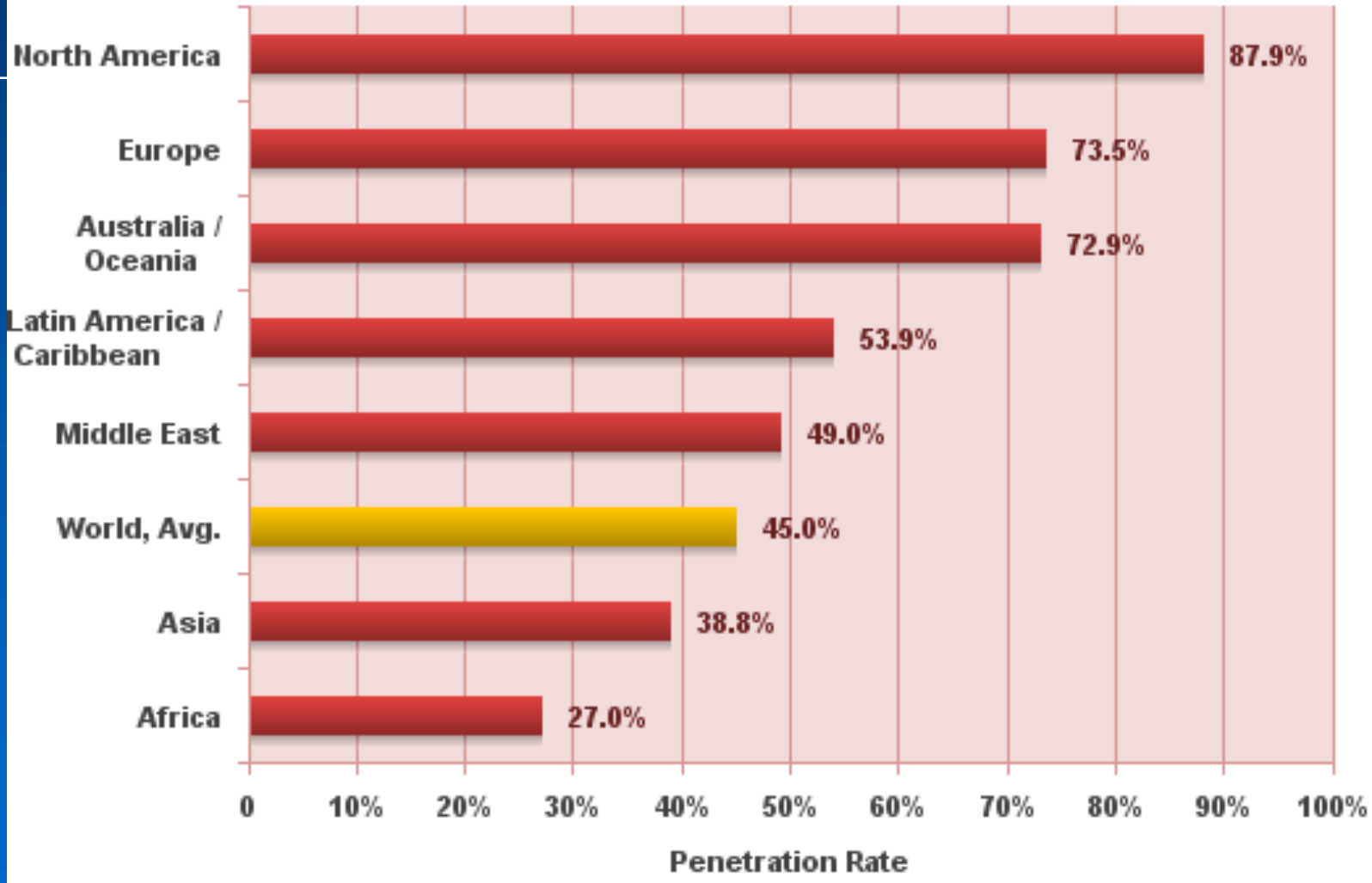


Internet Users in the World by Geographic Regions - 2015 Q2



Source: Internet World Stats - www.internetworldstats.com/stats.htm
3,270,490,584 Internet users estimated for June 30, 2015

World Internet Penetration Rates by Geographic Regions - 2015 Q2



Source: Internet World Stats - www.internetworldststs.com/stats.htm
Penetration Rates are based on a world population of 7,260,621,118 and 3,270,490,584 estimated Internet users on June 30, 2015.

Or look at it dynamically

- https://en.wikipedia.org/wiki/Global_Internet_usage
- http://www.internetlivestats.com/internet-users/

Internet growth (3)

- Why this explosive growth?
  - Decrease in price of end-user equipment: PCs, laptops etc.
  - Increase in portable devices that use batteries
    - And don't need wiring: wifi devices
    - Also Internet of Things (IoT)
  - Increase in useful applications
    - Not just commercial application
    - Personal applications, mapping , game playing, etc.
- The future? Internet of things…
- More info:
- http://www.internetworldstats.com