Imperial College London

Computer Networks and Distributed Systems

Introduction to the course

Course 527 – Spring Term 2014-2015

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Course Structure

- 1^{st} half: Distributed Systems
  - Covers basic distributed systems architectures, remote (object) interactions, remote procedure calls, security
- 2^{nd} half: Computer Networks
  - Covers basic principles of networking through examples of real technology
- Whilst networks are concerned with communicating data from one endpoint to another (or several) distributed systems help us design systems whose components are hosted on different computers

Course Structure

- 2 lectures + 1 tutorial each week
- 1 coursework
- Electronic handouts available from CATE
- Please ask questions!

Course Structure: Distributed Systems

- Overview of Distributed System Architecture
- Distributed Components and their Interaction
- RPC and Remote Invocation Implementation
- Security

Recommended Books (for DS)

- "Distributed Systems: Concepts and Design", George Coulouris, Jean Dollimore, Tim Kindberg, Gordon Blair Addison-Wesley, 2005 (5th Ed.)

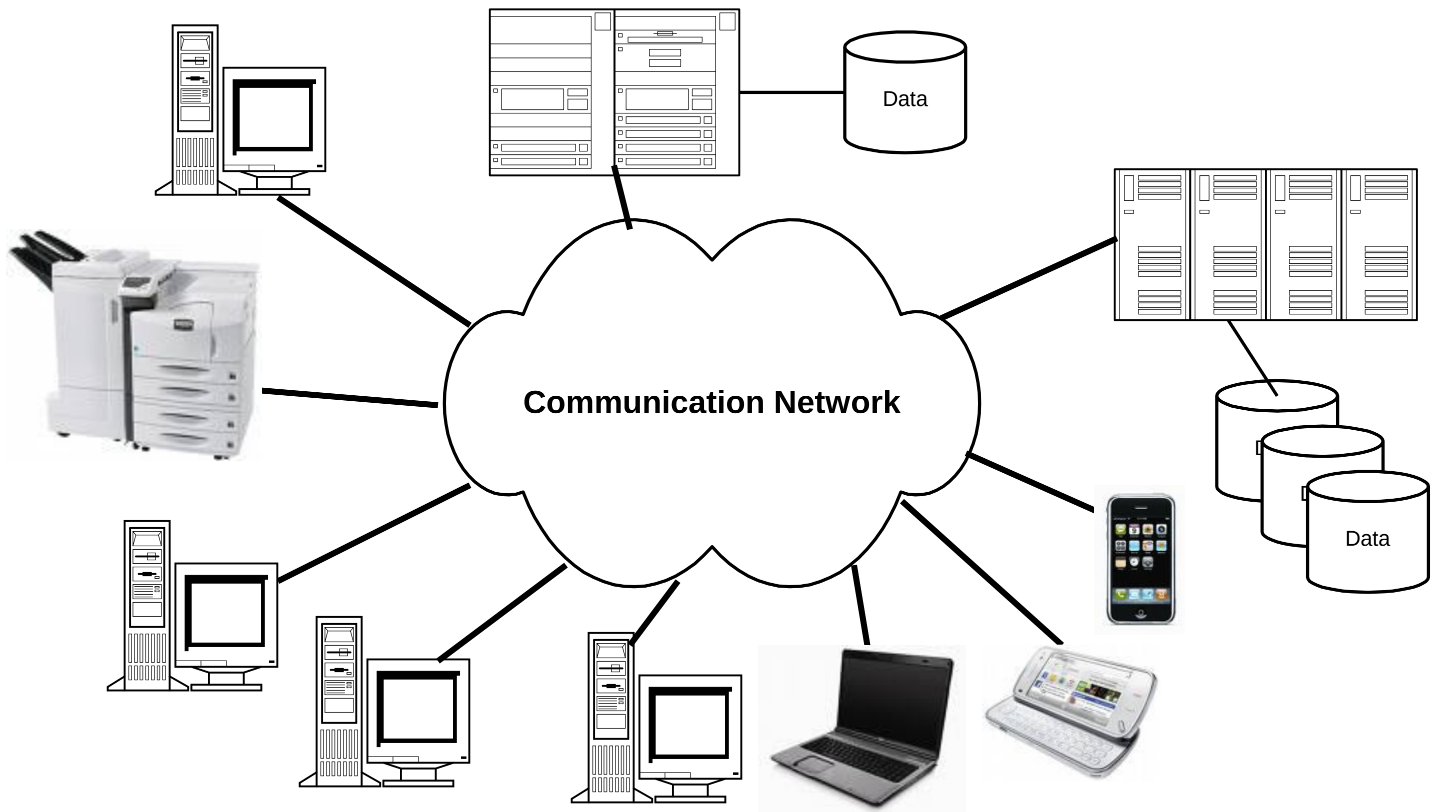
- "Distributed Systems: Principles and Paradigms" Andrew S Tanenbaum, Maarten Van Steen, Pearson Ed. (2nd Ed.)

- Acknowledgements:
  - Distributed Systems based on material by Morris Sloman and Emil Lupu
  - Some of the figures and images from external sources

Part 1: Distributed Systems Architecture

- Characteristics of Distributed Systems
- Distributed Design
- Peer-To-Peer
- Layering
- Transparencies
- Viewpoints

What is a Distributed System?

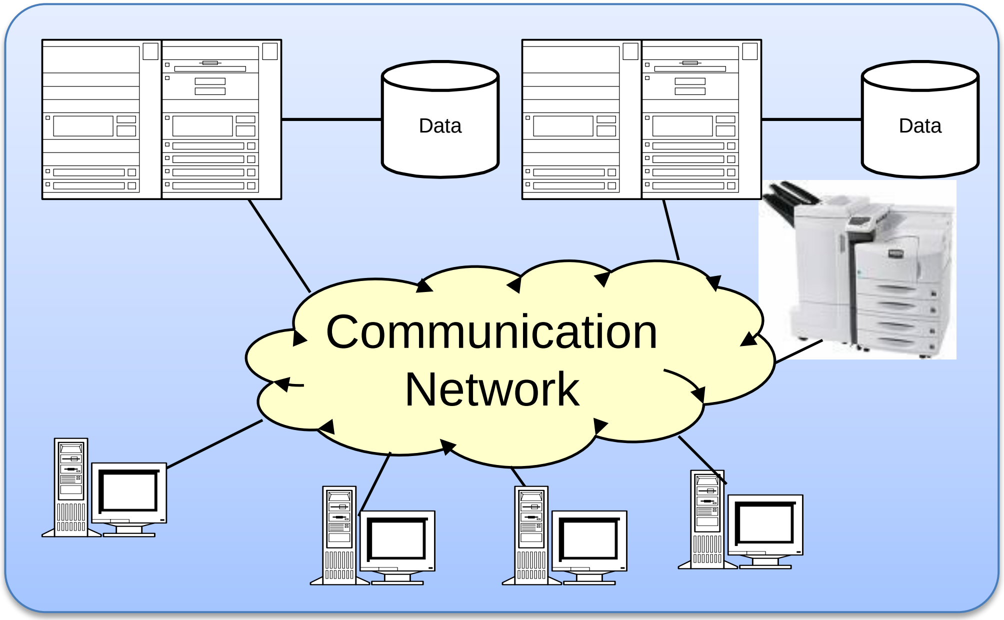


Definition

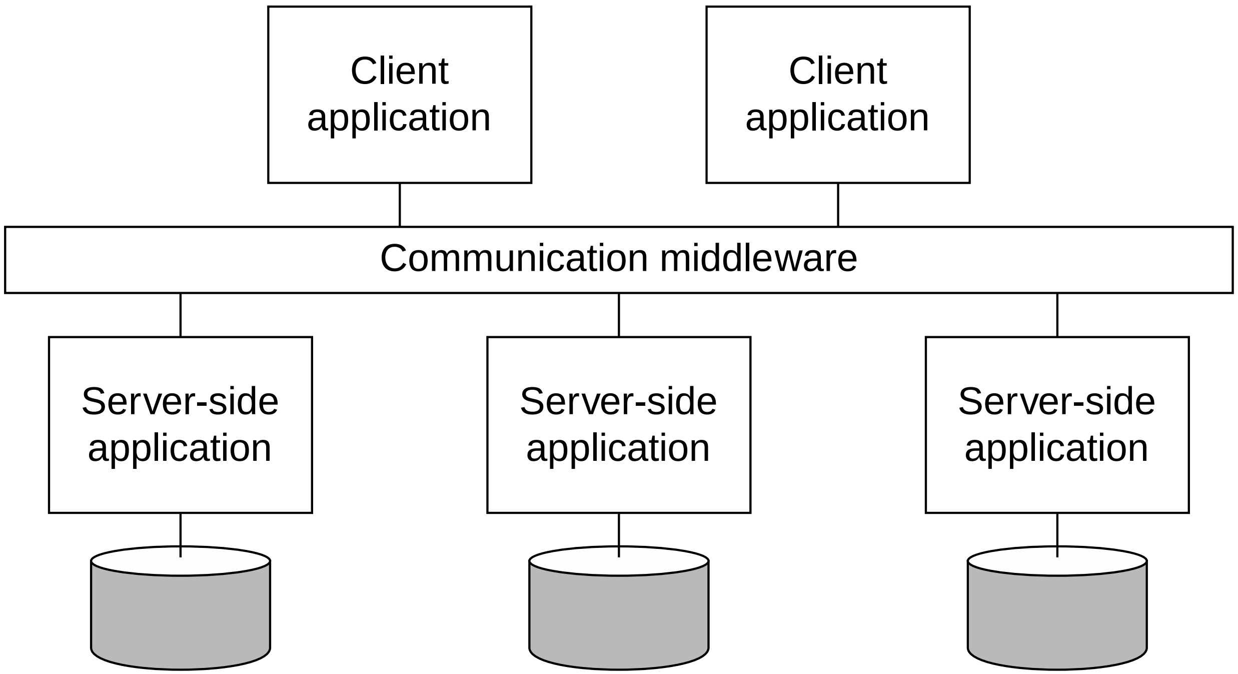
- A distributed system consists of a collection of autonomous computers interconnected by a computer network and equipped with distributed system software to form an integrated computing facility

- Components interact and cooperate to achieve a common goal

Processes co-ordinate by means of messages transferred over a communication network



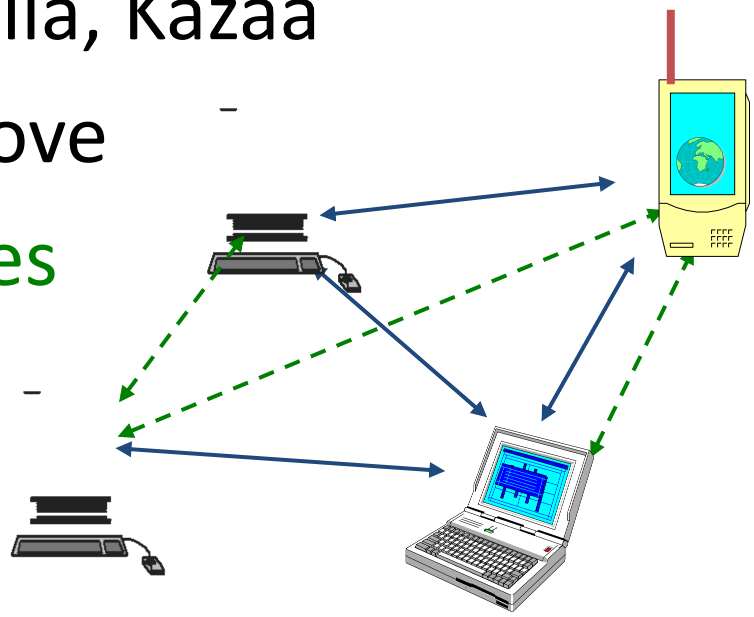
Enterprise Systems



- Remote Procedure Calls
- Message Oriented Middleware
- Publish/Subscribe Systems

Peer-to-peer (P2P)

- Very large scale – potentially millions of users
- Share processing e.g. Seti@home, United Devices, Avaki, Akamai
- 'Share' files e.g. Gnutella, Kazaa
- Collaboration e.g. Groove
- How to locate resources



Publish and query to directory ⟷

Get data from peers ← - - →

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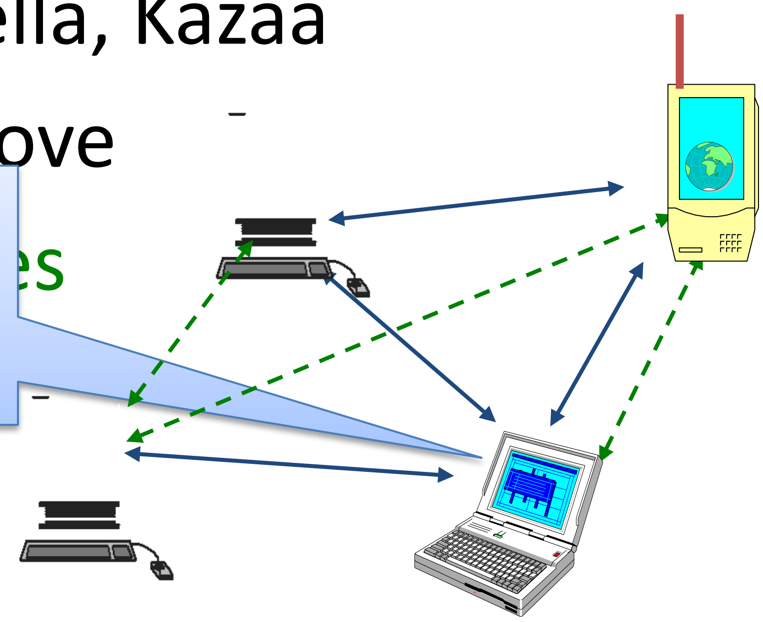
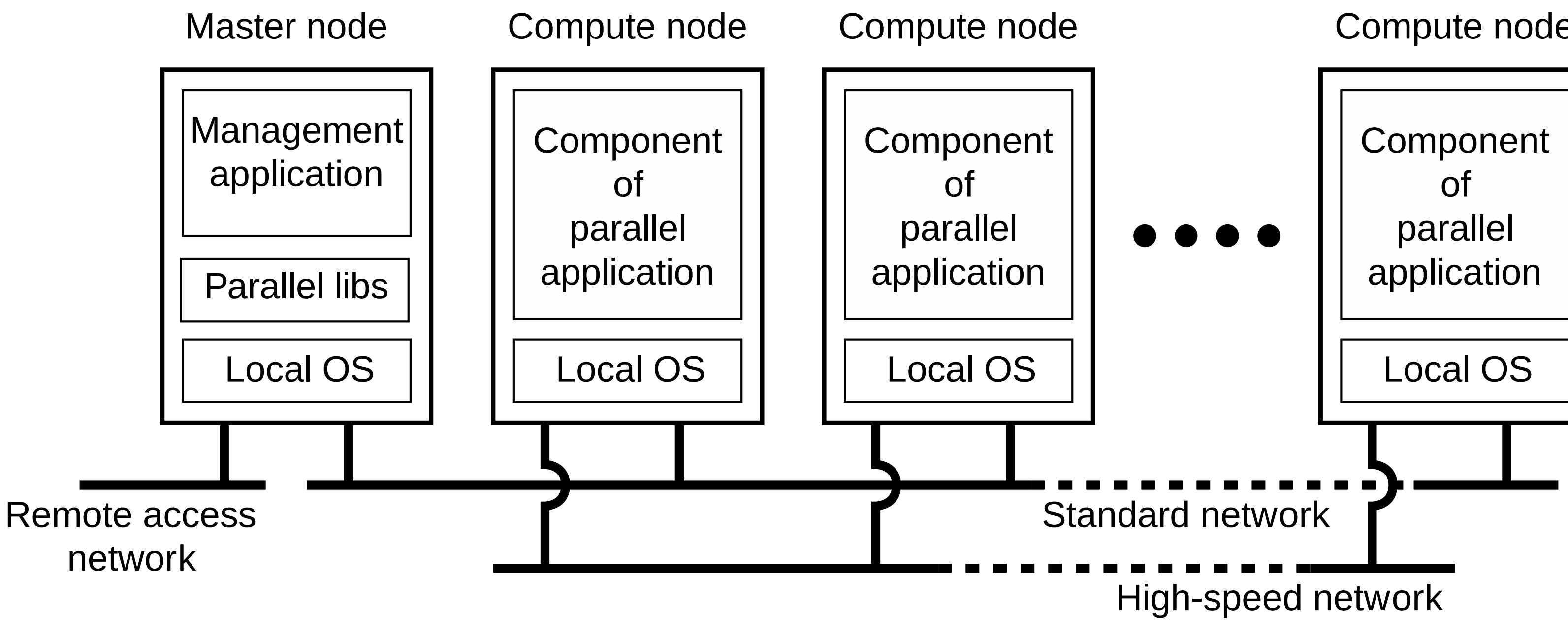
Where is the directory? Hard to find information



Publish and query to directory

Get data from peers

Computing Clusters

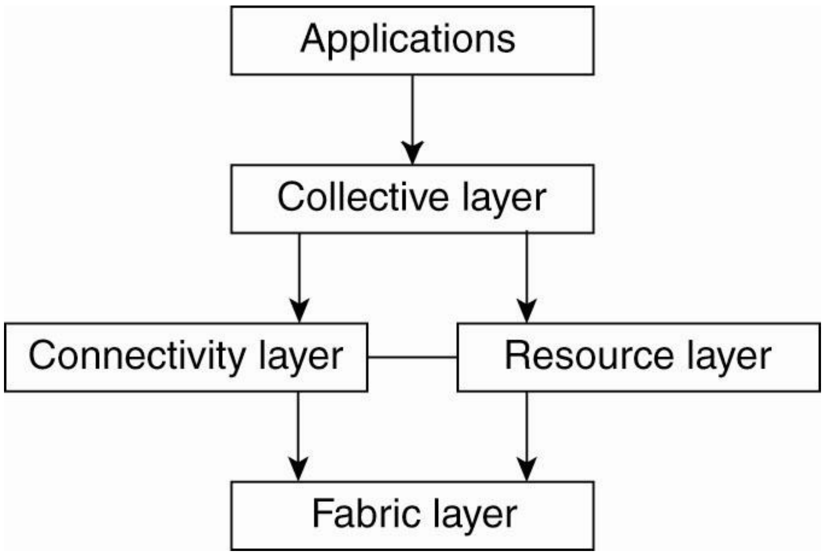


Generally used for parallel programming

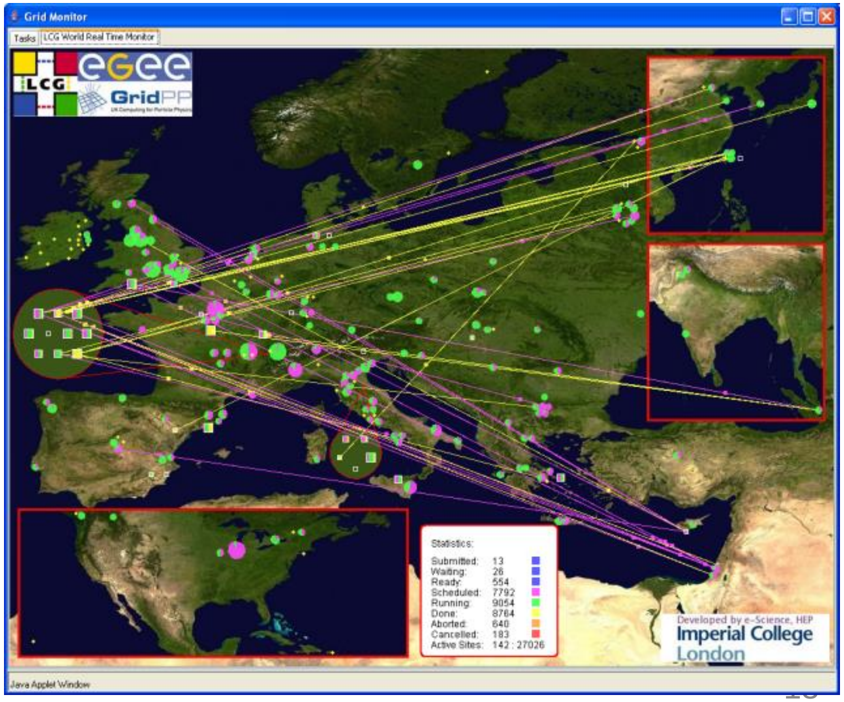
- Off-the-shelf computers interconnected by a high speed network
- Examples: Beowolf, CoW

Grid Computing

- Distributing computation and data across several sites

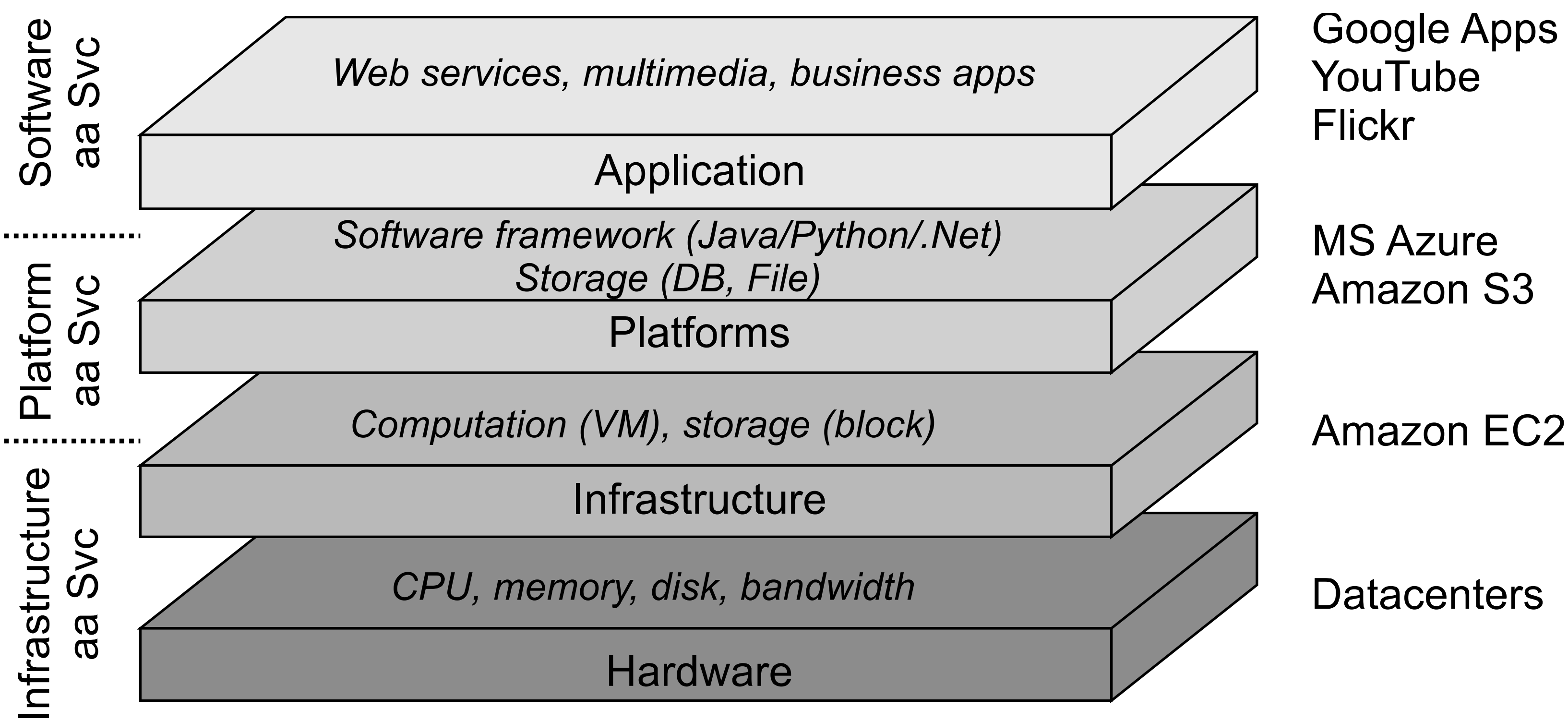


- Increasingly based on Web Service Architectures



- Examples: OGSA, Globus, OntoGrid

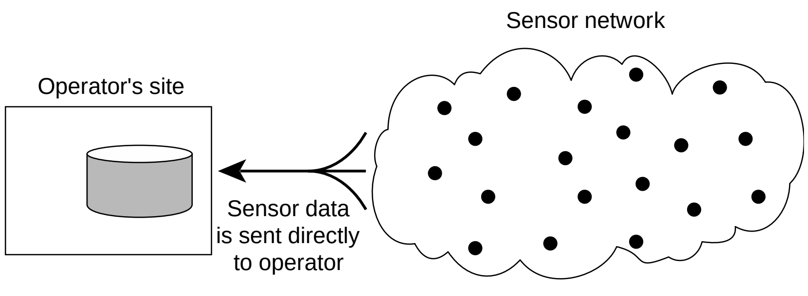
Cloud Computing



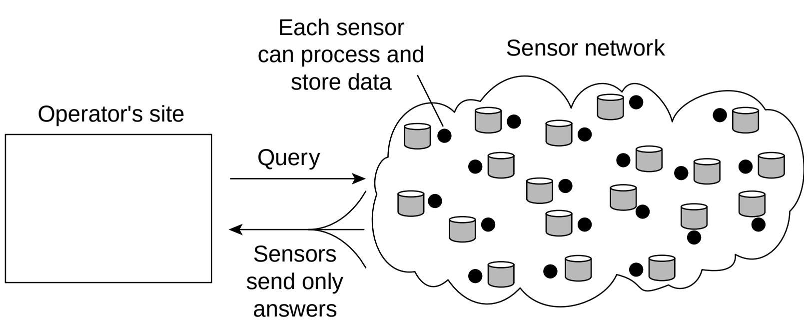
- Virtualisation of HW and SW infrastructure

(Distributed) Pervasive Systems

Wireless Sensor Networks



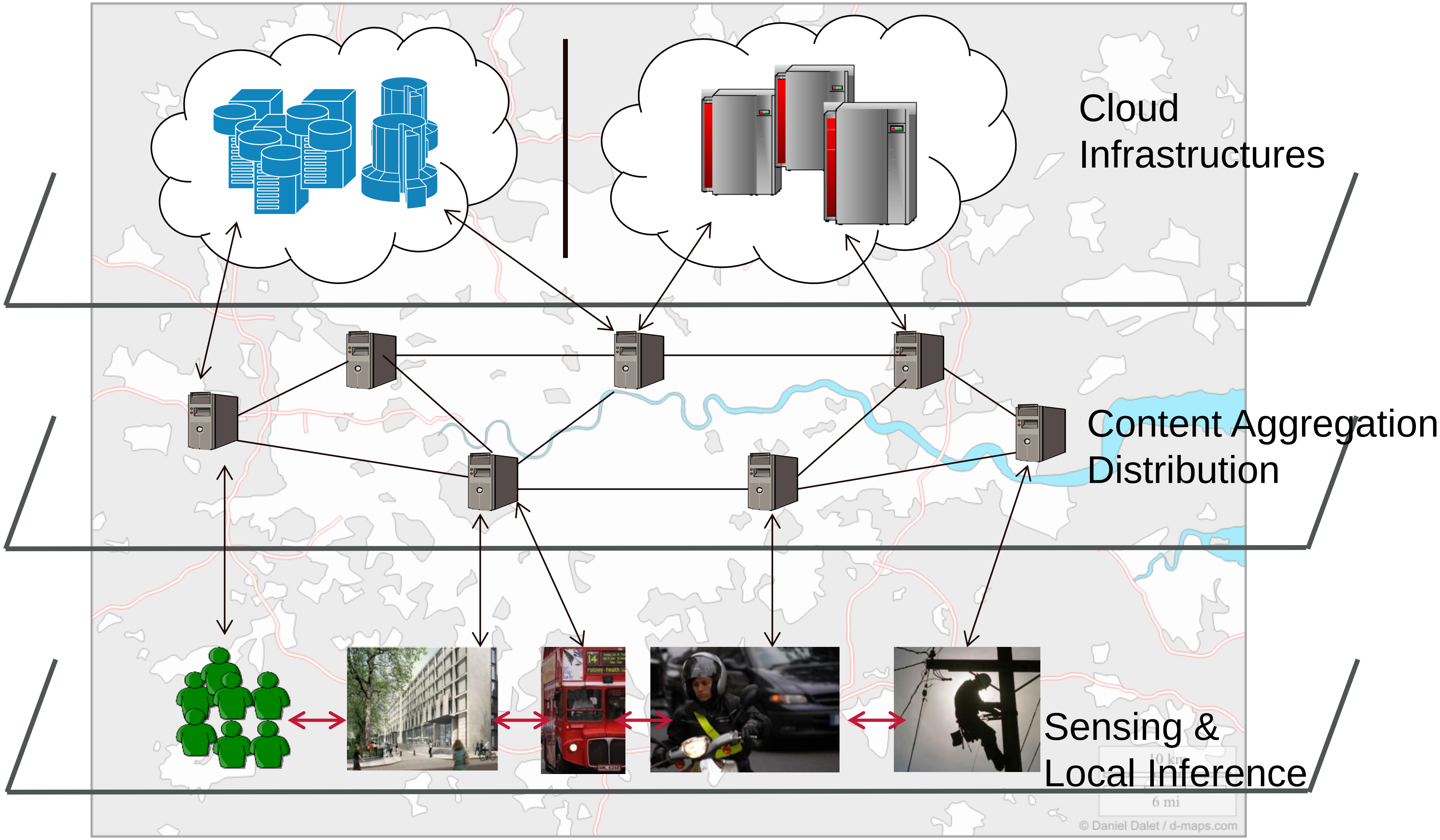
(a)



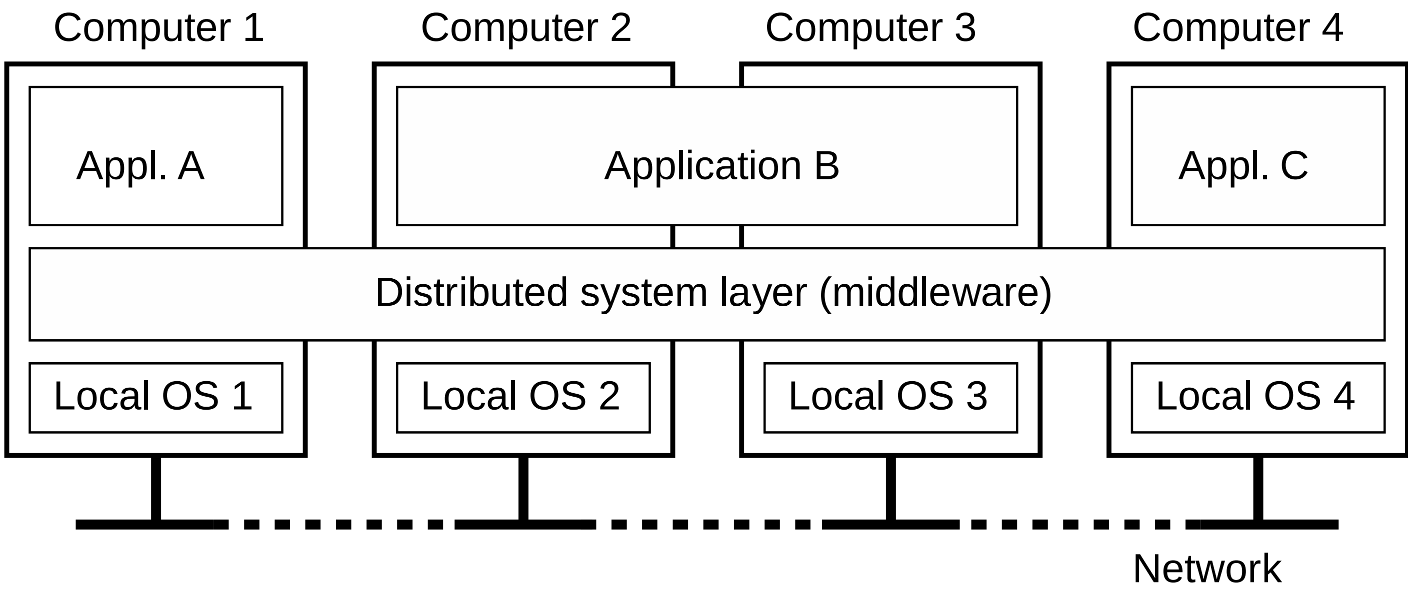
(b)

Body Sensor Networks

Large Scale Infrastructures



So What is a Distributed System?



- Abstracting from the specificities of every node to consider the computing environment as a single coherent system

- Requires: interaction abstractions, middleware and services

Dependence on Distributed Computing

Finance and commerce	eCommerce e.g. Amazon and eBay, PayPal, online banking and trading
The information society	Web information and search engines, ebooks, Wikipedia; social networking: Facebook and MySpace
Creative industries and entertainment	Online gaming, music and film in the home, user-generated content, e.g. YouTube, Flickr
Healthcare	Health informatics, online patient records, monitoring patients
Education	E-learning, virtual learning environments; distance learning
Transport and logistics	GPS in route finding systems, map services: Google Maps, Google Earth
Science	The Grid as an enabling technology for collaboration between scientists
Environmental management	Sensor technology to monitor earthquakes, floods or tsunamis

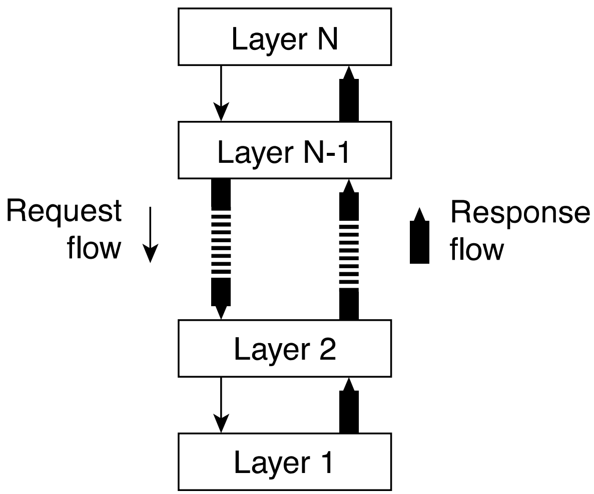
Characteristics/Advantages

- Resource sharing: remote access to shared facilities
- Fault tolerance: replication can remove failures
- Concurrency: reduce response time by local processing, improve throughput by parallelism
- Openness: vendor independence via clearly defined interfaces and use of standards
- Scalability: via multiple processors and multiple networks

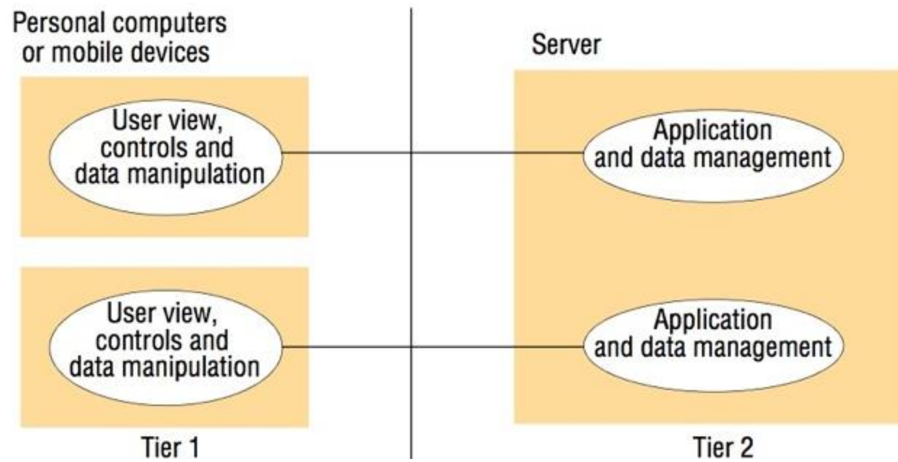
Characteristics/Advantages

- Modularity: simpler design, installation & maintenance
- Flexibility: incremental change of function & adaptation to new requirements
- Reflect application distribution
- But no global time: difficult to support causality and consistency

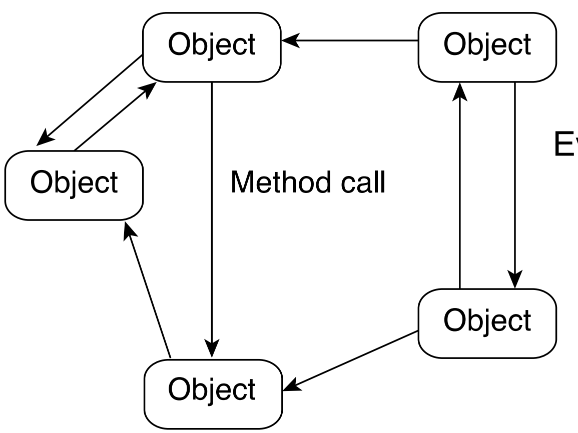
Architectural Styles



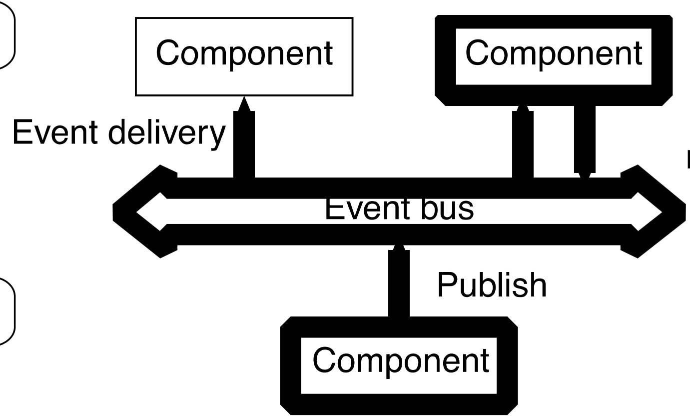
Layers



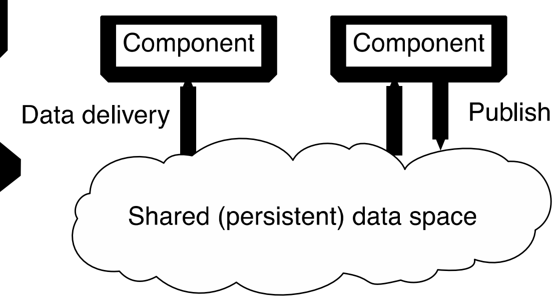
Tiers



Peers (Objects, Proc.,….)



Event Based

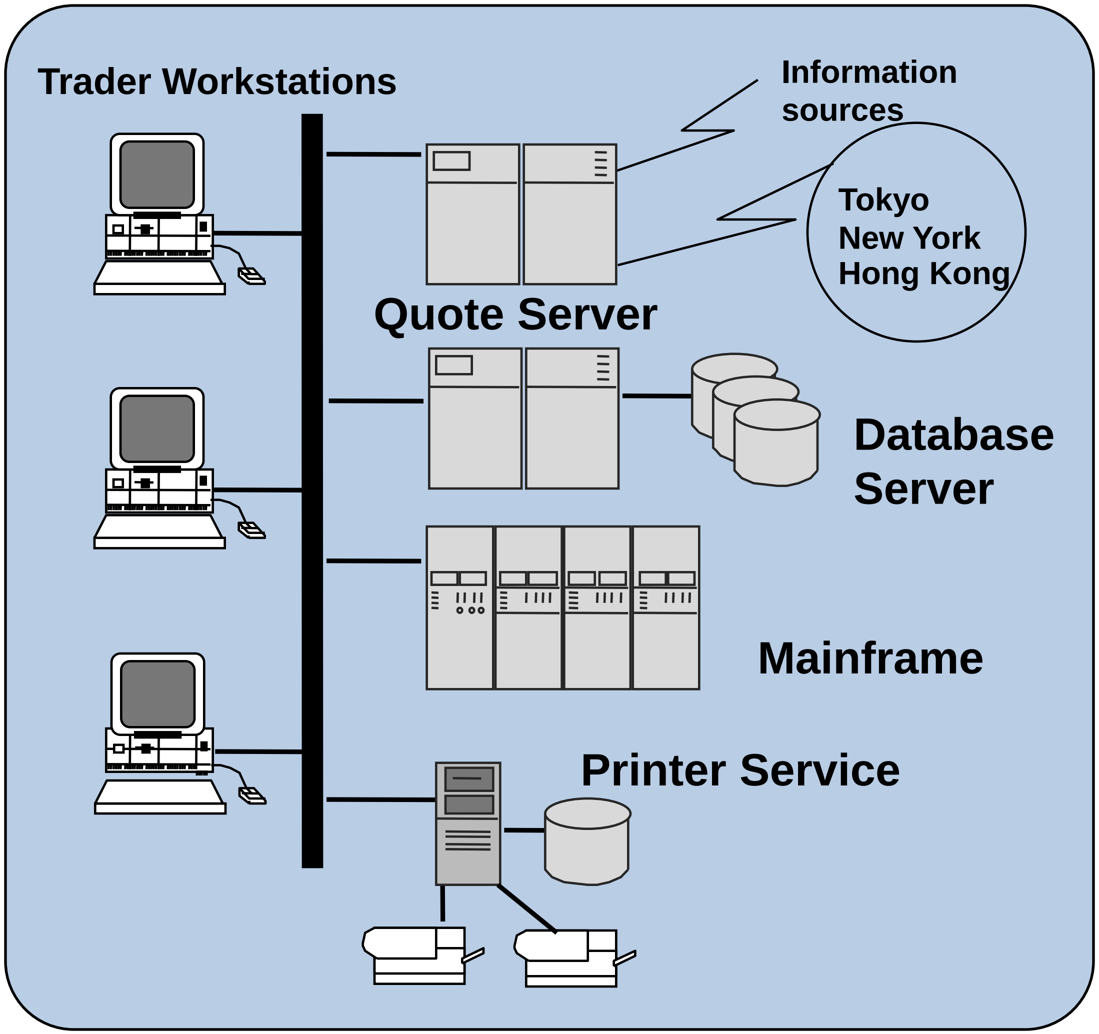


Shared memory based

Financial Trading: Requirements

- Required Functionality
  - Selective viewing of market data
  - Fast display management
  - Fast processing capabilities
  - Link between accounting & financial dealing
  - Risk management & hedging strategies
  - Use market data directly in analysis packages
  - Automatic record and bookkeeping
- Required Properties
  - Integrity → don't lose data
  - Reliability → don't go down
  - Speed → old news is not news
  - Extensibility/scalability → system matches business needs

Distributed Design



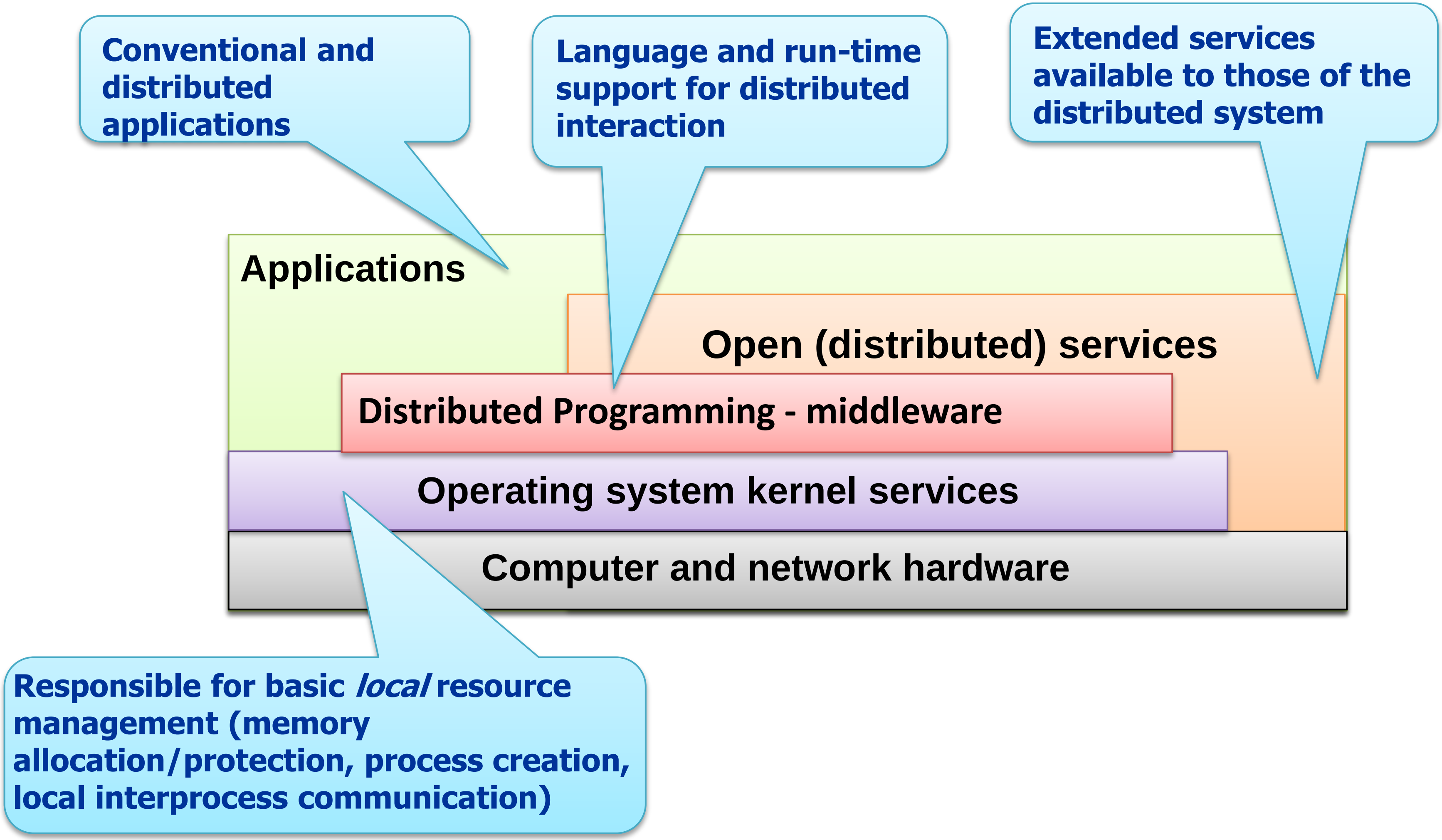
- Integrated digital and video
- Integrated data and news
- Links to positions, clearing and accounting
- Paperless trading
- Powerful workstations...
  - Colour charts, graphics
  - Real-time analysis
  - Expert systems

Architectural Approach

Data Broadcast and filtering – tagged messages

"Clients" register interest in particular kinds of data. Receive relevant data when broadcast, and filter out other data

Basic software structure



Services

- Open services
  - Support the introduction of new services
  - Provide access to distributed services, including the coordination required for remote resource use (sharing, protection, synchronisation, recovery....)
  - e.g. Jini resource discovery

- Distributed programming support
  - Supports interaction (such as remote procedure call) for conventional languages and support for special purpose languages.
  - e.g. Java RMI, RPC

Distribution Transparencies

It is often useful to hide distribution from the user – design goals which can be difficult to achieve

Access	uniform access whether local or remote
Location	access without knowledge of location i.e. location independent naming
Concurrency	sharing without interference – requires synchronisation
Replication	hides use of multiple components e.g. for fault tolerance
Failure	concealment of faults by replication or recovery
Migration	hides movement of components e.g. for load balancing
Performance	use of scheduling and reconfiguration to hide performance variations
Scaling	permits expansion without changing system structure or algorithms
Heterogeneity	transforming information between different representations

Open Distributed Processing - RM

Viewpoint = abstract representation of a system NOT phases in lifecycle model

- Enterprise Viewpoint
  - Overall goals, policies & organisational structure
  - Roles & activities within organisation(s)
  - Policies & constraints regarding cross-organisation interactions
  - Community: configuration of objects established to meet an objective – specifies roles, relationships and policies

- Information Viewpoint
  - Modelling of information structures, information flows and knowledge representation
  - Includes constraints on data
  - No distinction between manual & automated information processing

Open Distributed Processing - RM

- Computational Viewpoint
  - Programming functions – IPC, object interfaces
  - Application program structuring – independent of computer system on which it will run
  - No distinction between processing & storage object
  - Includes configuration – object instantiation and bindings

- Engineering Viewpoint
  - OS, communication system, database – implementation issues
  - Provision of transparency mechanisms – fault tolerance, persistence etc.
  - Processors & networks are visible

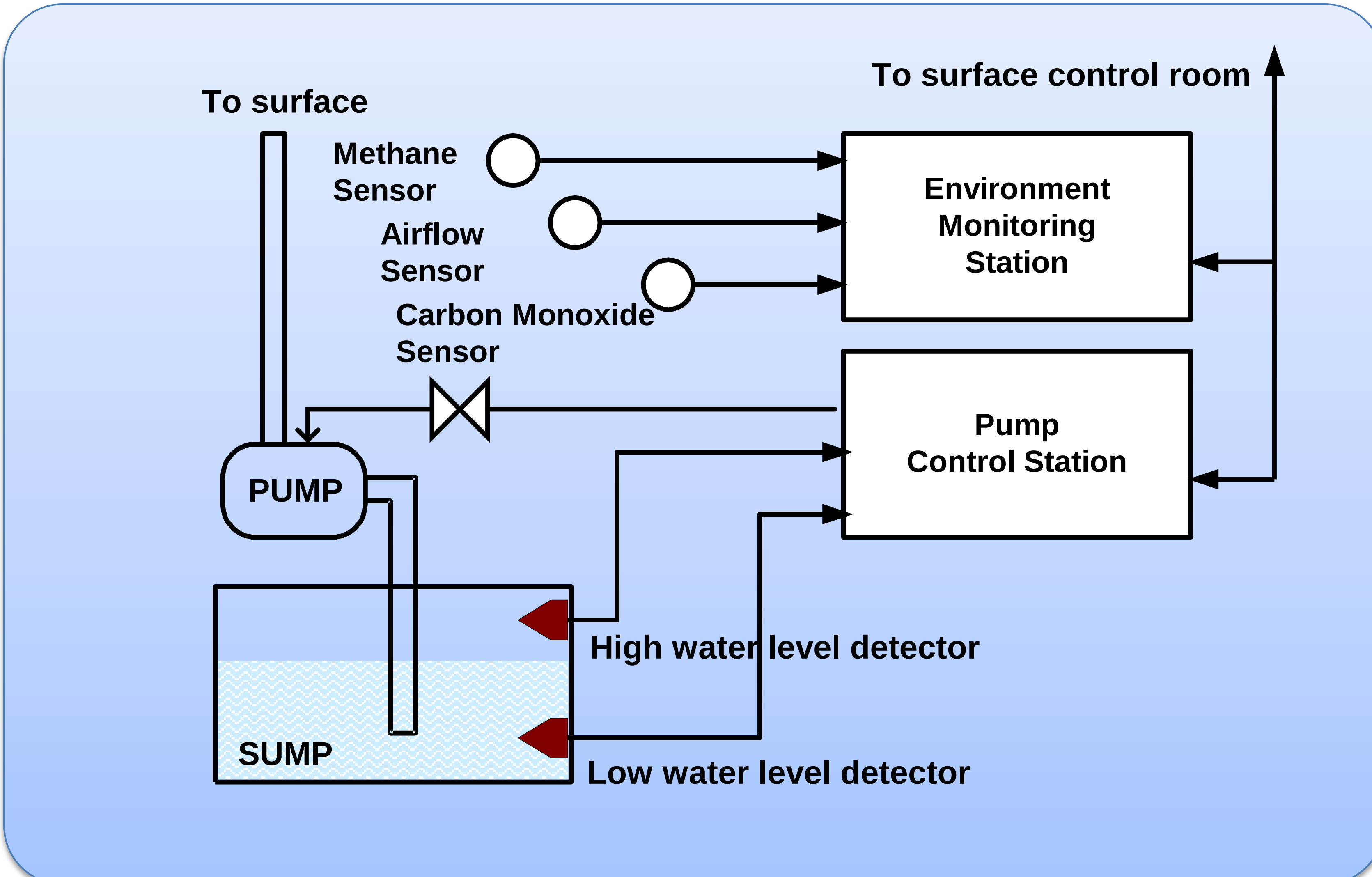
- Technology Viewpoint
  - Realised components from which distributed systems are built.
  - Particular OS (Unix, Windows), protocols (FTP, TCP/IP), processors (Intel, Sparc, ARM)

Example: Pump for Mine Drainage

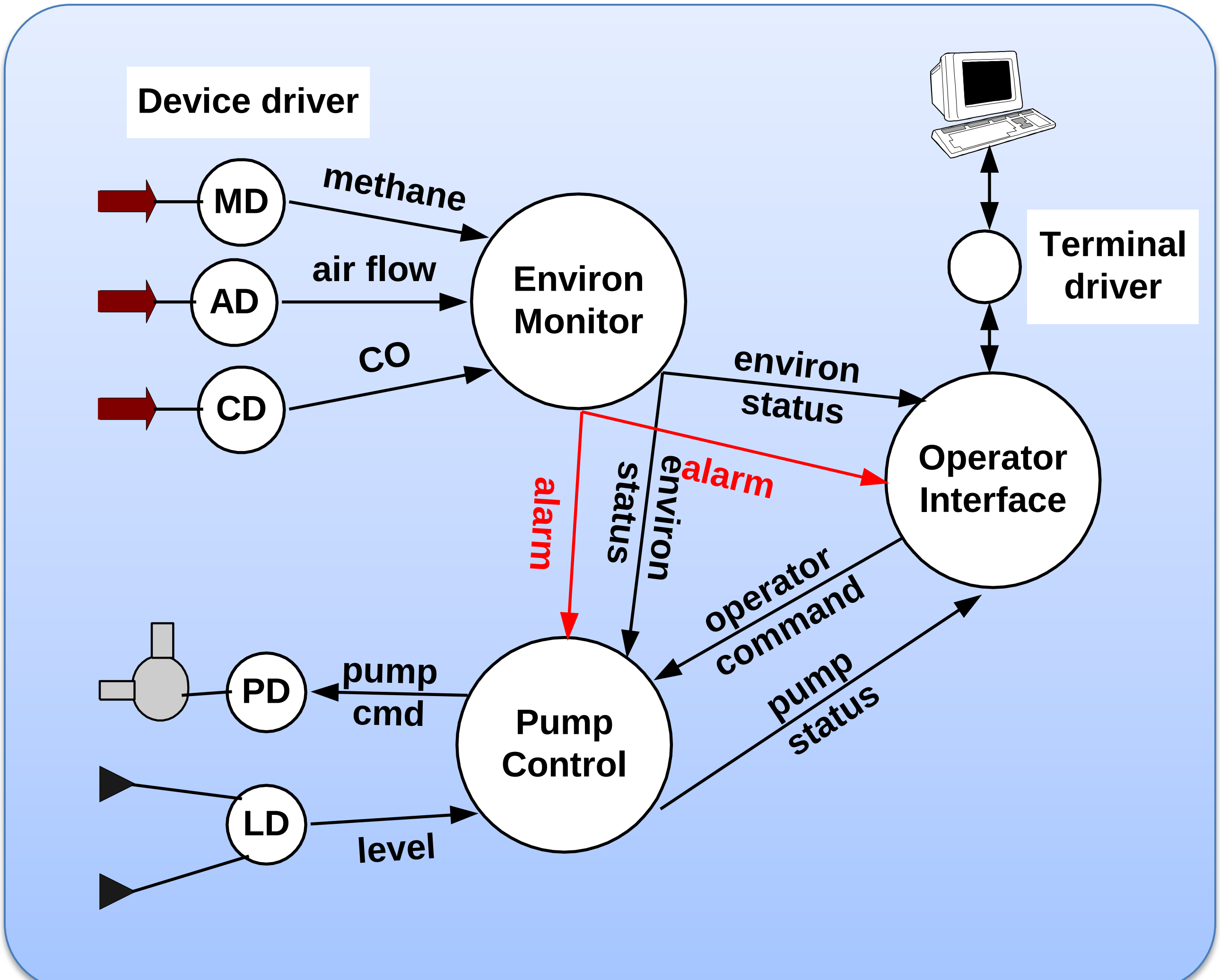
- The pump is situated underground in a coal mine, and so for safety reasons it must not be started or continue running when the percentage of methane in the atmosphere exceeds a set safety limit. The pump controller obtains information on methane levels by communicating with a nearby environment monitoring station. As well as methane, this station also monitors carbon monoxide and airflow velocity. The environment monitoring station provides information to the surface and other plant controllers as well as to the pump controller

- Once start has been enabled by a command from the surface, the pump runs automatically, controlled by the water level as sensed by the high and low level detectors. Detection of high level causes the pump to run until low level is reached. The surface may deactivate the pump with a stop command, and also query the status of the pump

Pump System Overview



Pump Control Schematic



Data Flow Diagrams

Component Processes describe the functions of the system

Data flows = data type + direction

Data Dictionary for Pump System

```
pump cmd    = (on, off)
level       = (high, low)
methane     = real
airflow     = real
alarm       = signal

environ status  = methane + airflow + CO

operator cmd    = (start, stop, status)

pump status =  (stopped, lowstop, methanestop,
running)
```

Distributed System Design Approach

- Enterprise View
  - Specify requirements and identify interactions with the environment
  - Identify main processing components – processes or threads of control
  - Assume 1 process per device

- Information View
  - Identify data flows – direction and data types (dictionary)
  - Ignore how interactions are initiated or types of interaction primitives

Distributed System Design Approach

- Computation View
  - Decide on interaction primitives
  - Decide on control flow i.e. whether data is pushed or pulled, e.g. whether controllers are polled or event driven
  - Specify component interfaces = interactions + signatures (parameter types)
  - Specify component functions in terms of outline code and data structures
- Engineering View
  - Optimise and allocate to physical nodes

Design Issues

- The following design issues will be addressed in this course:
  - **Communication**: process interaction and synchronisation paradigms
  - Distributed system **service provision**
  - **Security** to maintain confidentiality and protect against unauthorised access

Architecture Summary

- What are distributed systems – definition
- Why are they of interest – potential benefits
- Where are they used – applications

- Architecture
  - Viewpoint decomposition
  - Architectural Style

- Main Design aspects