

# MECH3023: Building Energy Management & Control Systems

<http://www.hku.hk/bse/mech3023/>



## System Architecture



*Dr. Sam C M Hui*

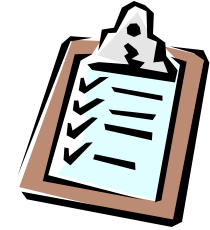
Department of Mechanical Engineering

The University of Hong Kong

E-mail: [cmhui@hku.hk](mailto:cmhui@hku.hk)

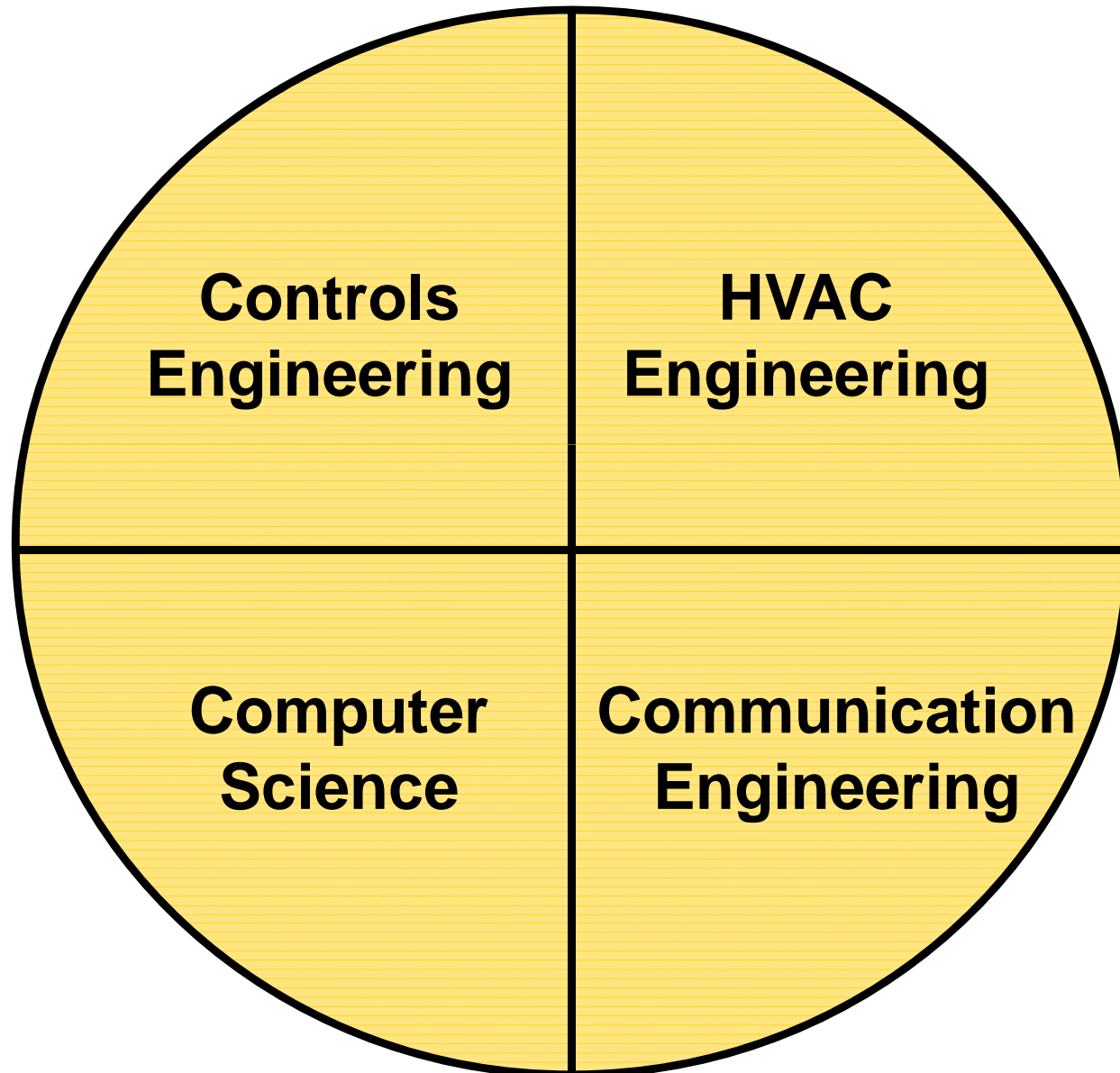
Feb 2010

# Contents



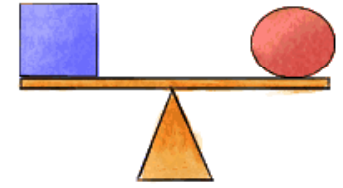
- Basic Concepts
- OSI Seven-layer Model
- Key Issues
- Interoperability
- BAS Case Study

Nowadays, BAS/BMS involves knowledge of many disciplines.

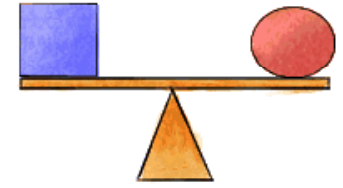


**Keyword: “Communicate”**

# Basic Concepts

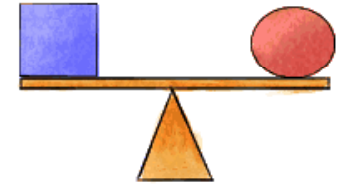


- **Architecture** (computer) [[www.webopedia.com](http://www.webopedia.com)]
  - A design. The term architecture can refer to either hardware or software, or to a combination of hardware and software. The architecture of a system always defines its broad outlines, and may define precise mechanisms as well.
  - An open architecture allows the system to be connected easily to devices and programs made by other manufacturers. Open architectures use off-the-shelf components and conform to approved standards. A system with a closed architecture, on the other hand, is one whose design is proprietary, making it difficult to connect the system to other systems.



# Basic Concepts

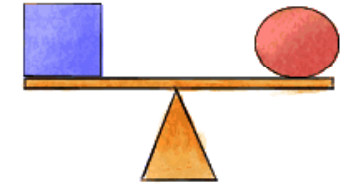
- A system architecture is the design or set of relations between the parts of a system
  - It can best be thought of as a representation of an existent (or to be created) system, and the process and discipline for effectively implementing the design(s) for such a system.
  - The set of relations (that is, embedded information) which an architecture describes may be expressed in hardware, software, or something else



# Basic Concepts

- Terminology & definitions
  - See more info on [[www.webopedia.com](http://www.webopedia.com)]
    - Online dictionary for computer and Internet definitions
- Data communication standard by ISO (International Organization for Standardization)
  - [Open Systems Interconnection \(OSI\) reference model](#) provides the guidelines for DDC systems and electronic system communications

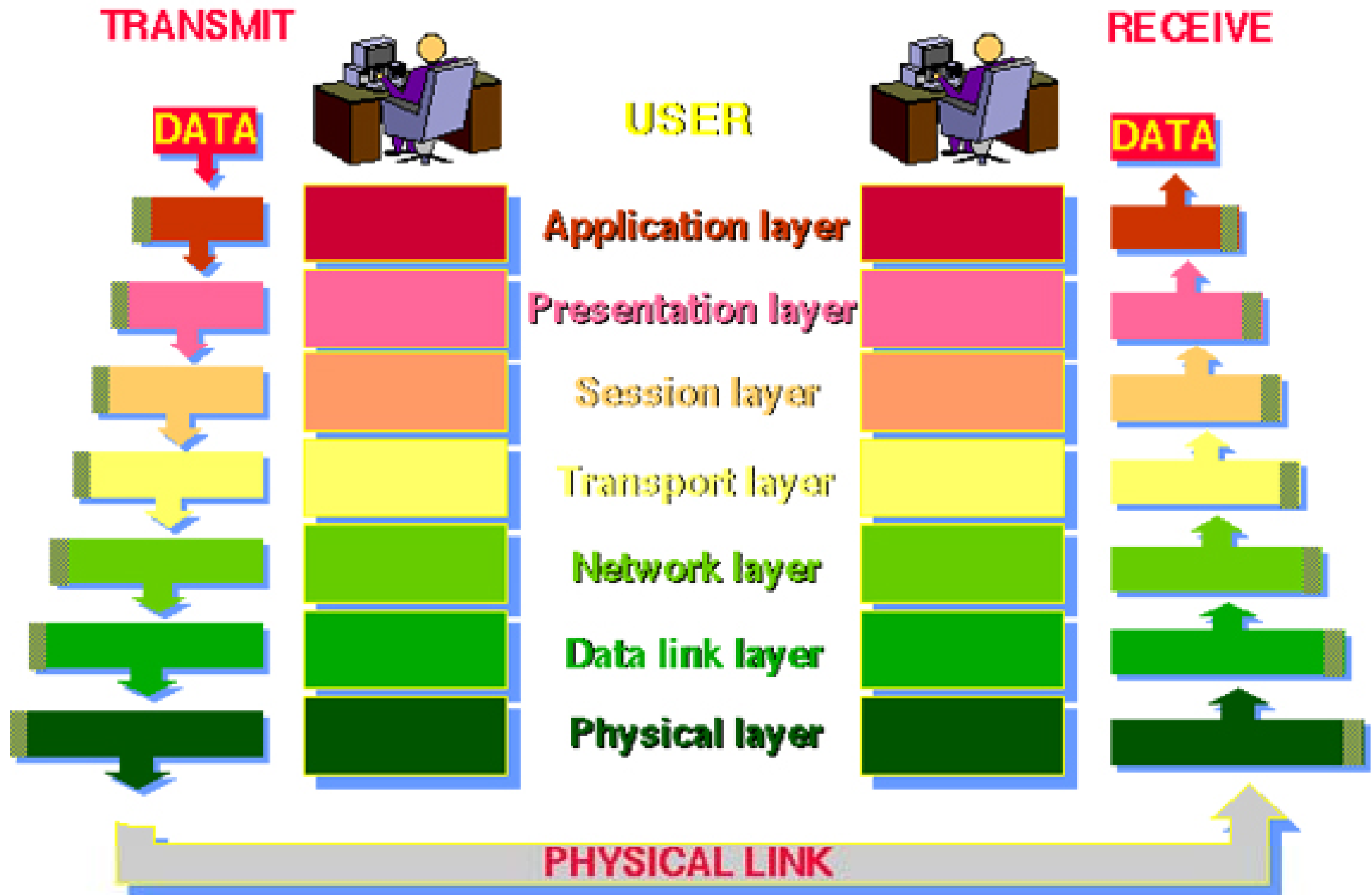
# OSI Seven-layer Model



- Network layers
  - OSI Seven-layer reference model
    - Level 1 – Physical Layer
    - Level 2 – Data Link Layer
    - Level 3 – Network Layer
    - Level 4 – Transport Layer
    - Level 5 – Session Layer
    - Level 6 – Presentation Layer
    - Level 7 – Application Layer



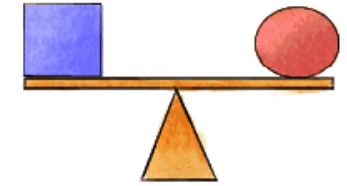
# THE 7 LAYERS OF OSI



(Source: [www.webopedia.com](http://www.webopedia.com))



# OSI Seven-layer Model



- Level 1 – Physical Layer



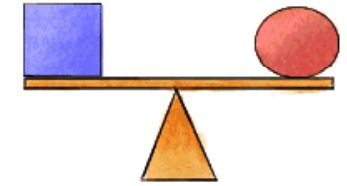
- Defines physical/actual hardware connections
- Purpose: electrical interconnection (e.g. ‘wire’)
- Services: media-specific details, transceiver type

- Level 2 – Data Link Layer



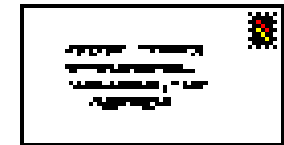
- Defines local network access methods
- Purpose: media access and framing
- Services: framing, data encoding, media access, error checking

# OSI Seven-layer Model



- Level 3 – Network Layer

- Defines destination addressing
- Purpose: destination addressing
- Services: destination addressing, packet routing

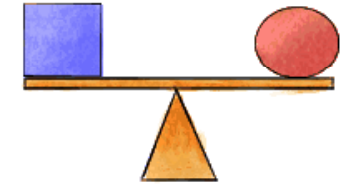


- Level 4 – Transport Layer

- Defines status & two-way communication
- Purpose: end-to-end reliability data transfer
- Services: acknowledgments, service type, duplicate detection, flow control



# OSI Seven-layer Model



- **Level 5 – Session Layer**

- Defines types & quality of services
- Purpose: remote actions
- Services: dialogue, remote procedure calls, connection recovery

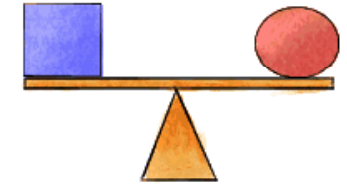


- **Level 6 – Presentation Layer**

- Defines, converts & decodes messages
- Purpose: data interpretation
- Services: network variables, application messages, foreign frames

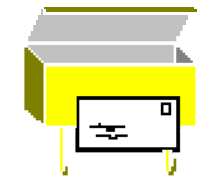


# OSI Seven-layer Model

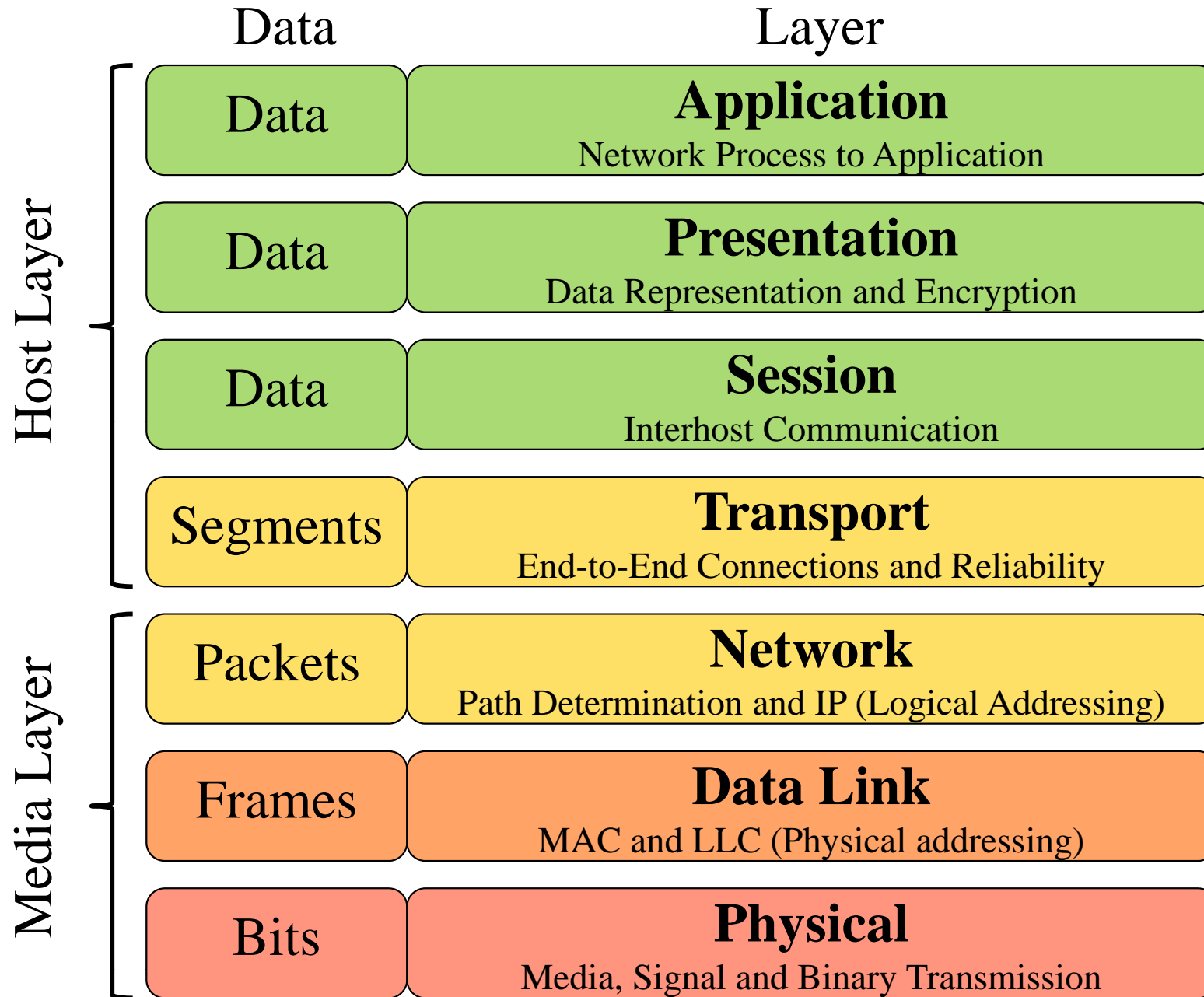


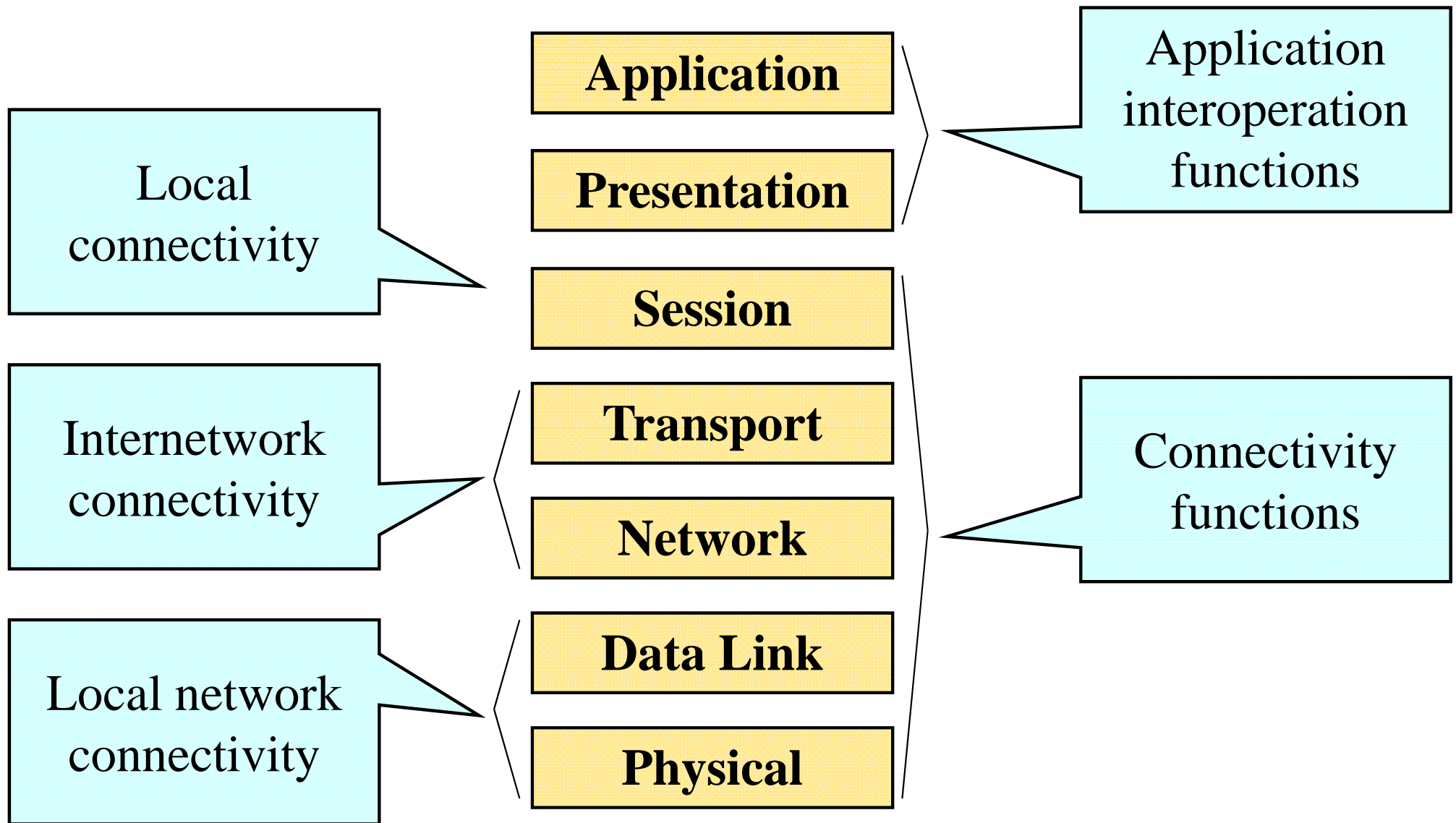
- Level 7 – Application Layer

- Defines application network service
- Purpose: application program
- Services: standard objects & types, file transfer, network service

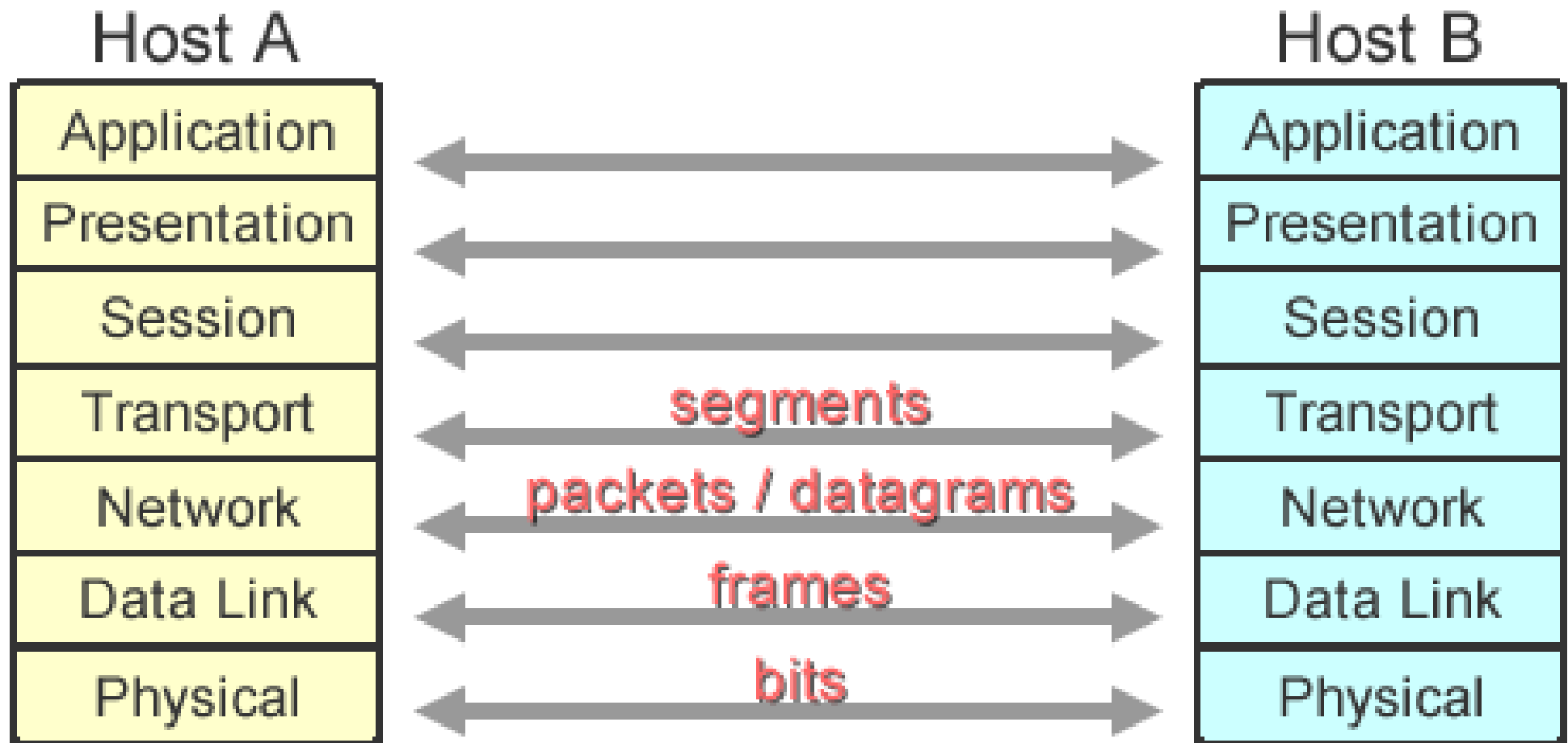


# Brief summary of the OSI 7-layer model

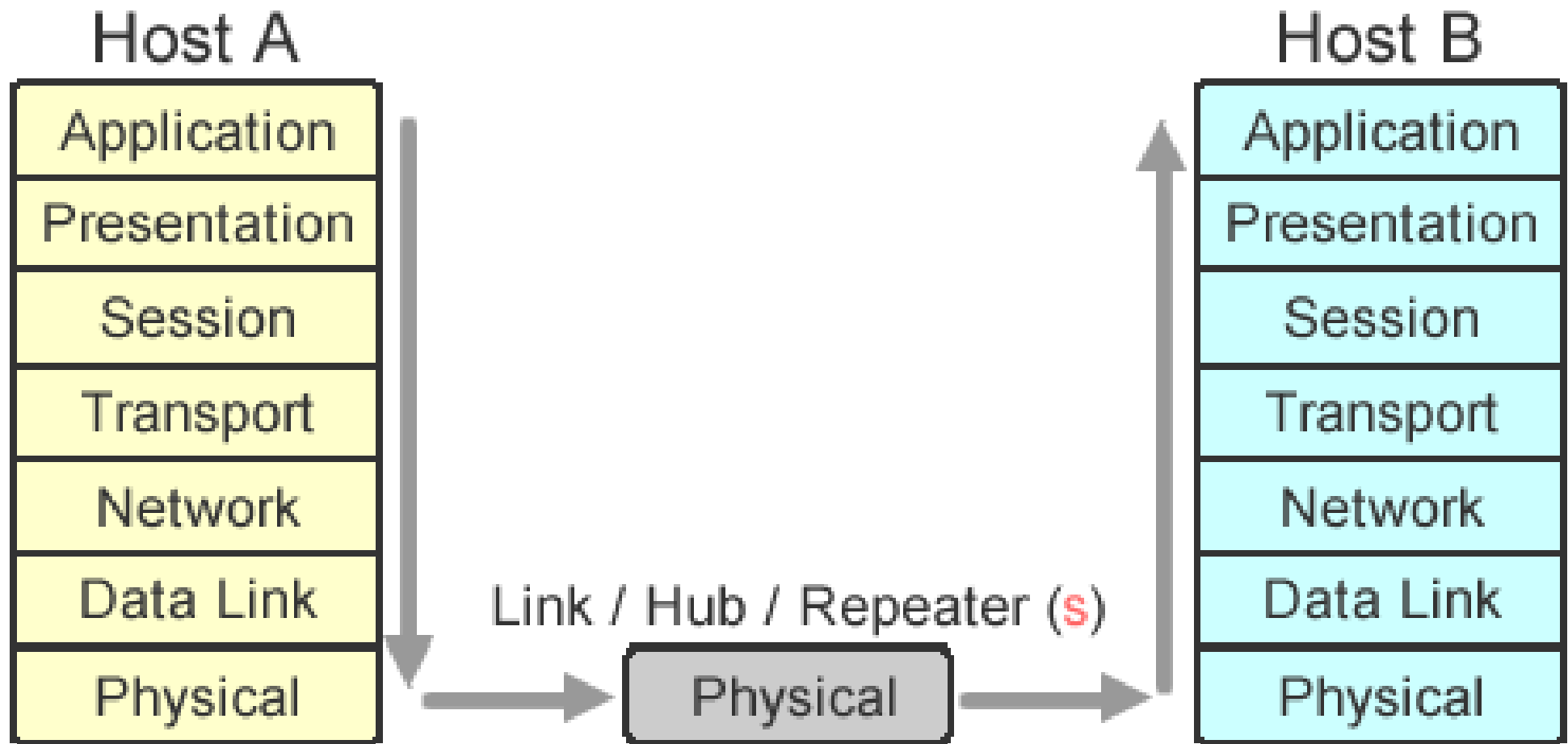




Functions of OSI 7-layer model

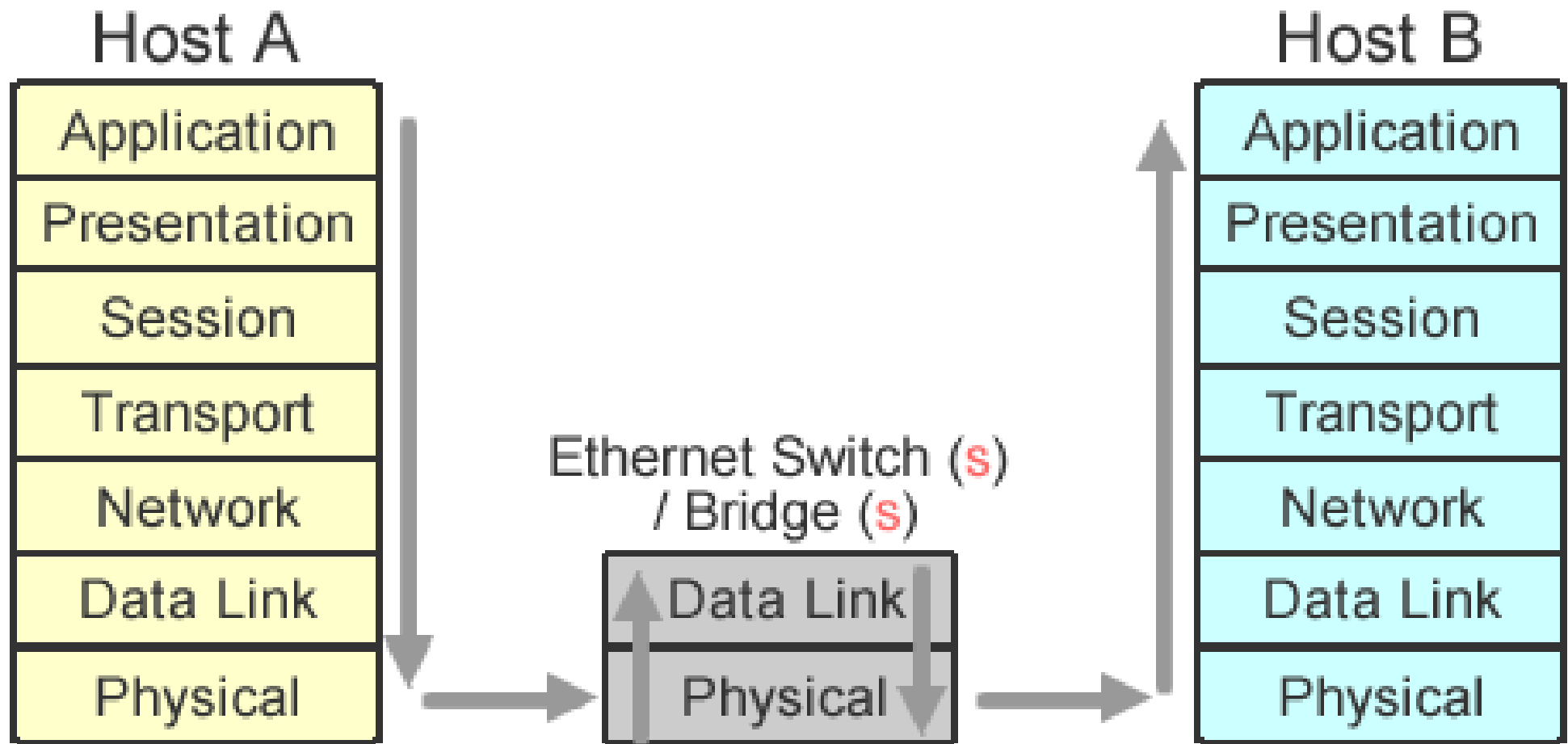


Communication of OSI 7-layer model

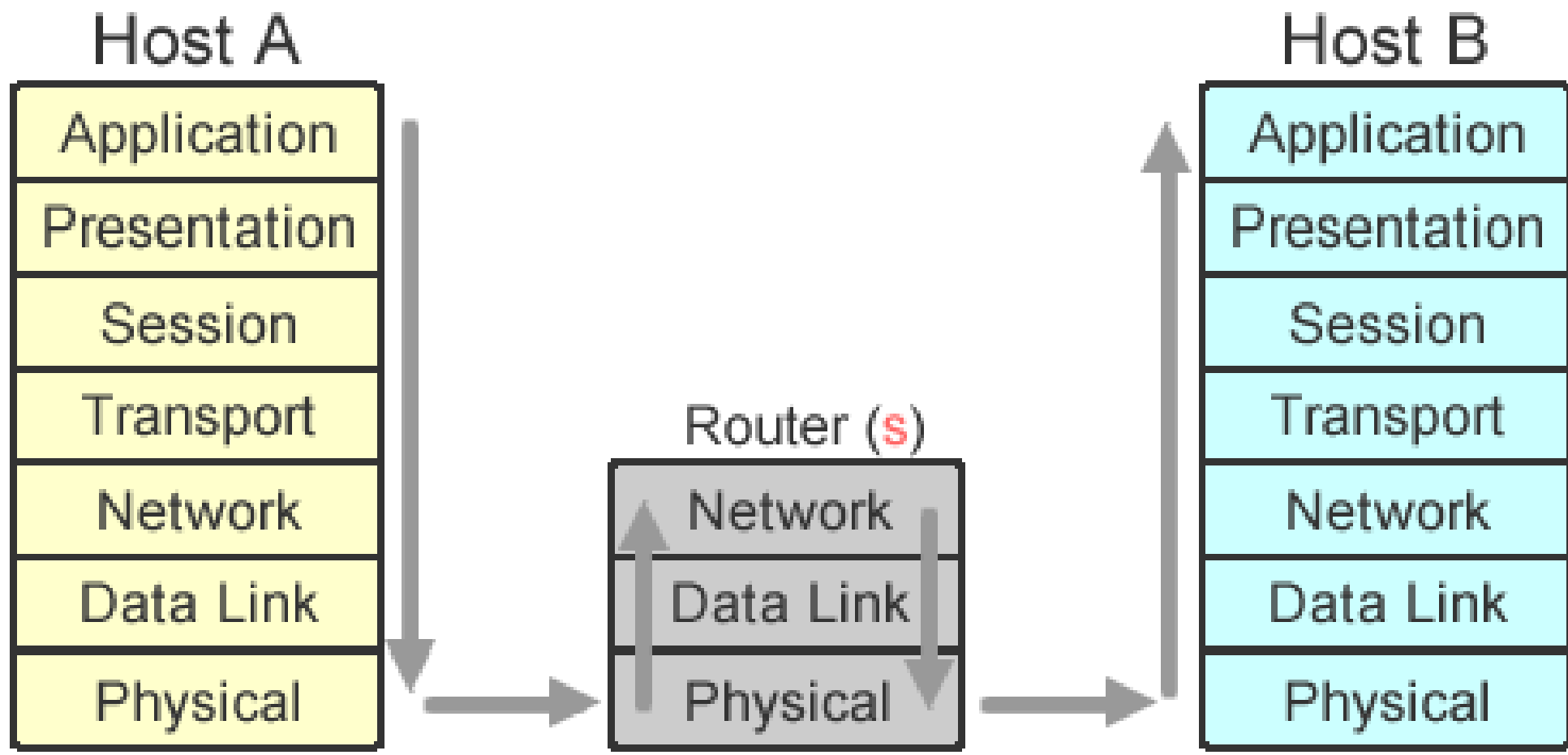


Connection at Layer 1 (Physical)

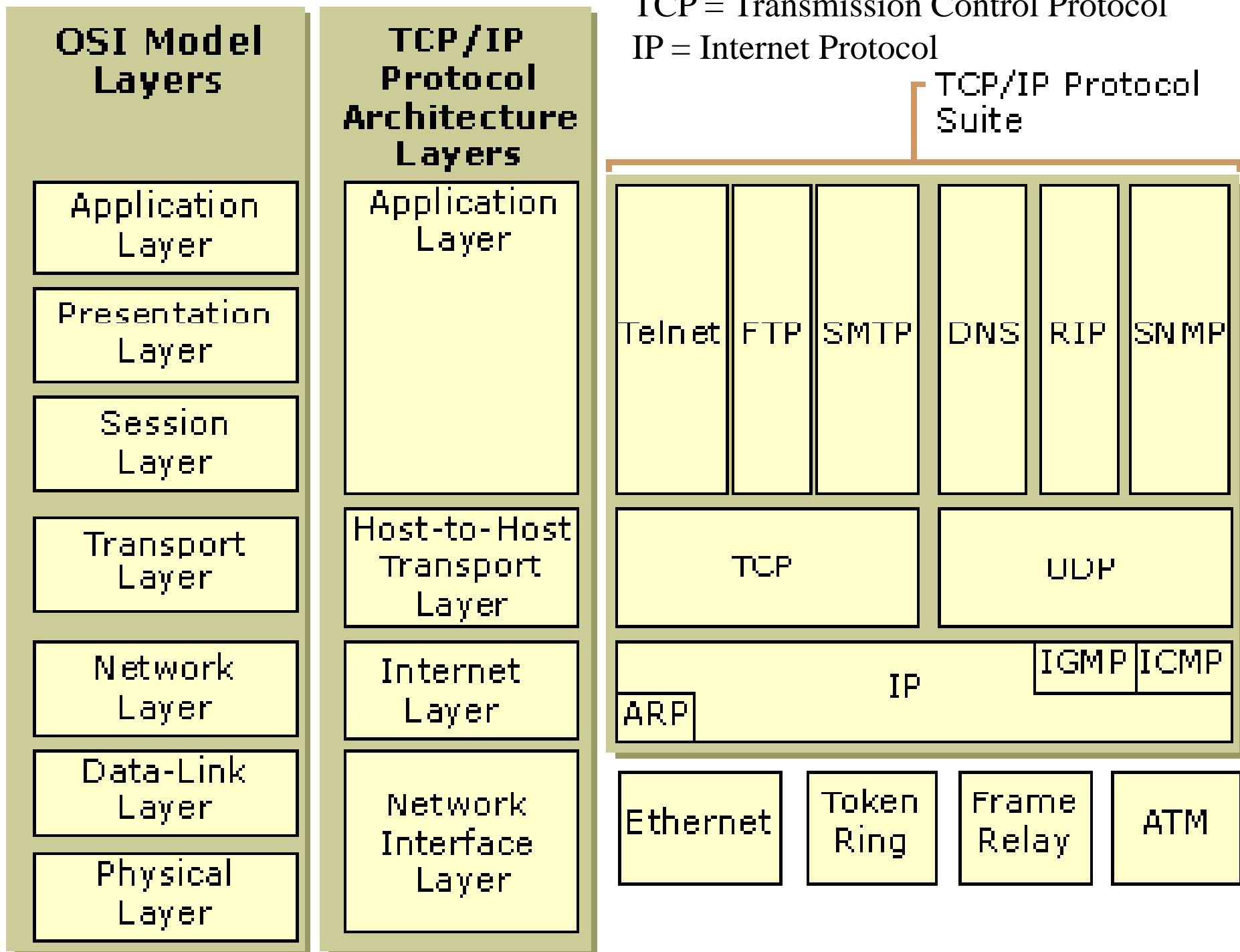




Connection at Layer 2 (Data Link)



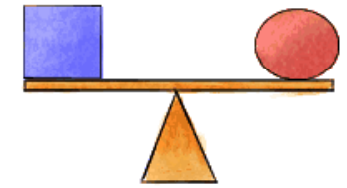
Connection at Layer 3 (Network)



TCP = Transmission Control Protocol  
 IP = Internet Protocol

Comparison of OSI model and TCP/IP layers

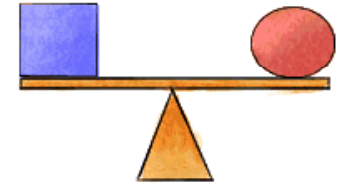
# OSI Seven-layer Model



- How to remember the 7 layers of OSI model?

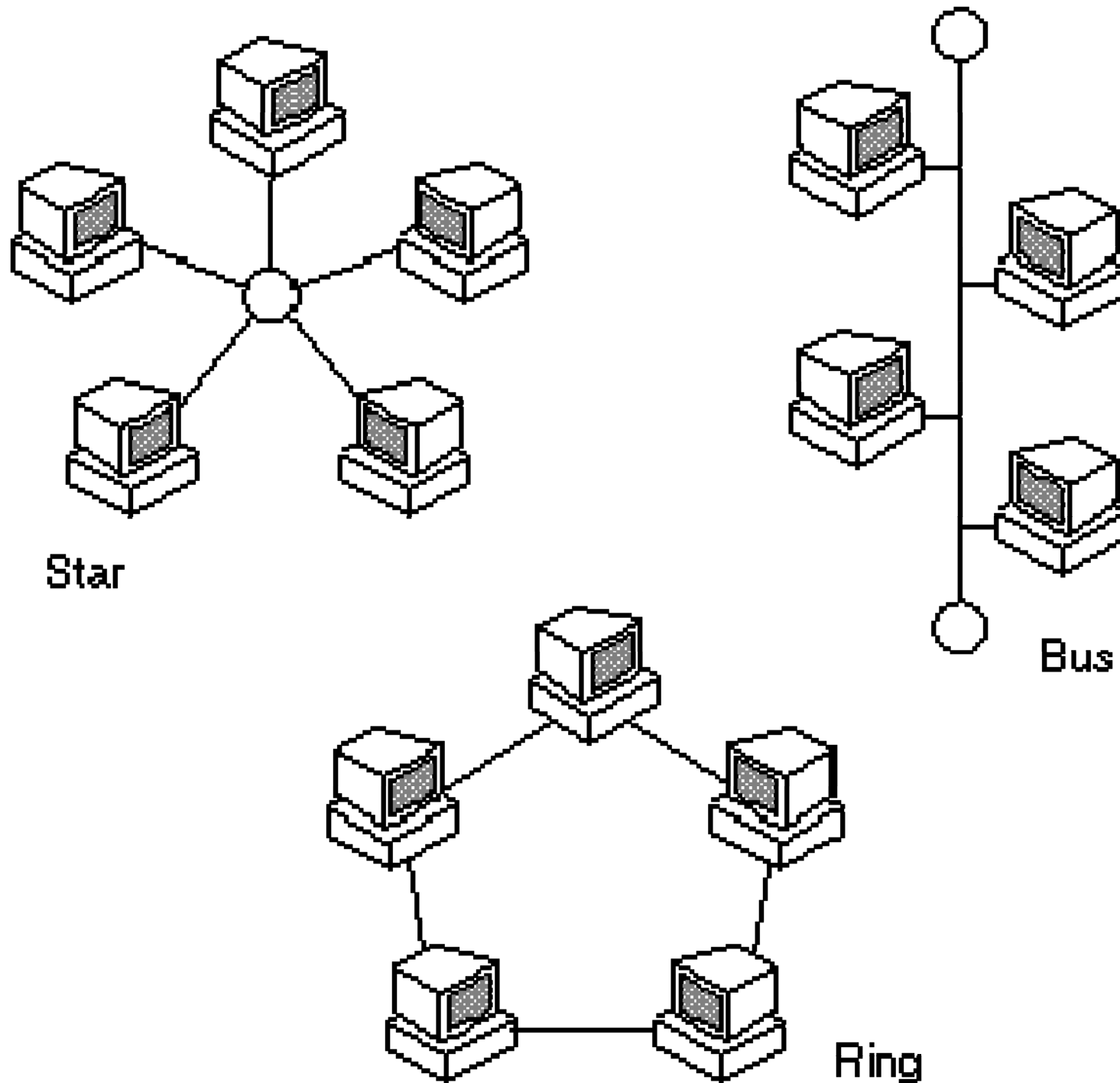
- All People Seem To Need Data Processing
- Please Do Not Throw Sausage Pizza Away





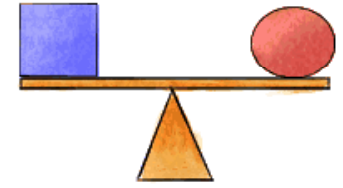
# Key Issues

- DDC control system architecture: key issues
  - Topology (拓撲)
    - Geometric layout (physical or logical) of the wiring between participating nodes
  - Protocol (協定)
    - Agreed-upon format or standard
    - Such as the network access method (data link layer)
  - Media (媒體)
    - Physical/actual communication medium (wiring)
    - Such as twisted pairs (TP) cable

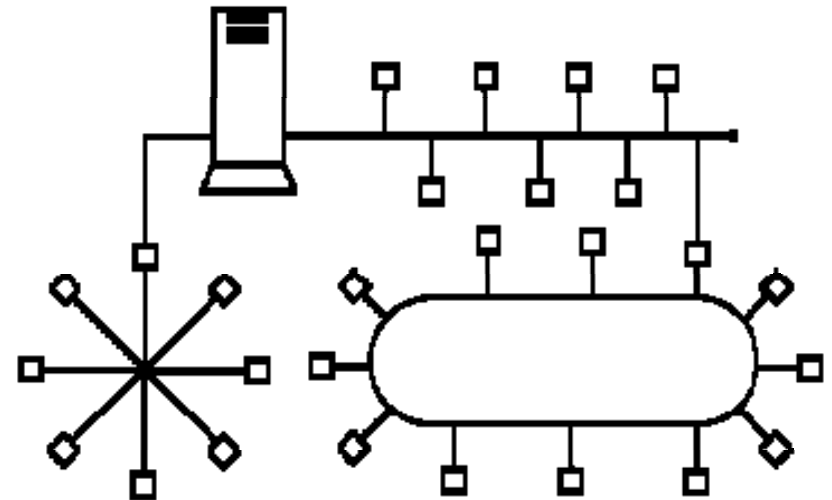


Topologies or layout of control network

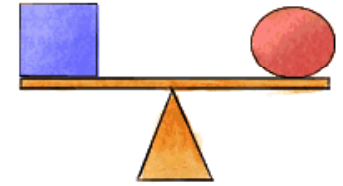
# Key Issues



- Topologies (physical wiring)
  - Bus topology
  - Star topology
  - Ring topology
  - Free/hybrid topology



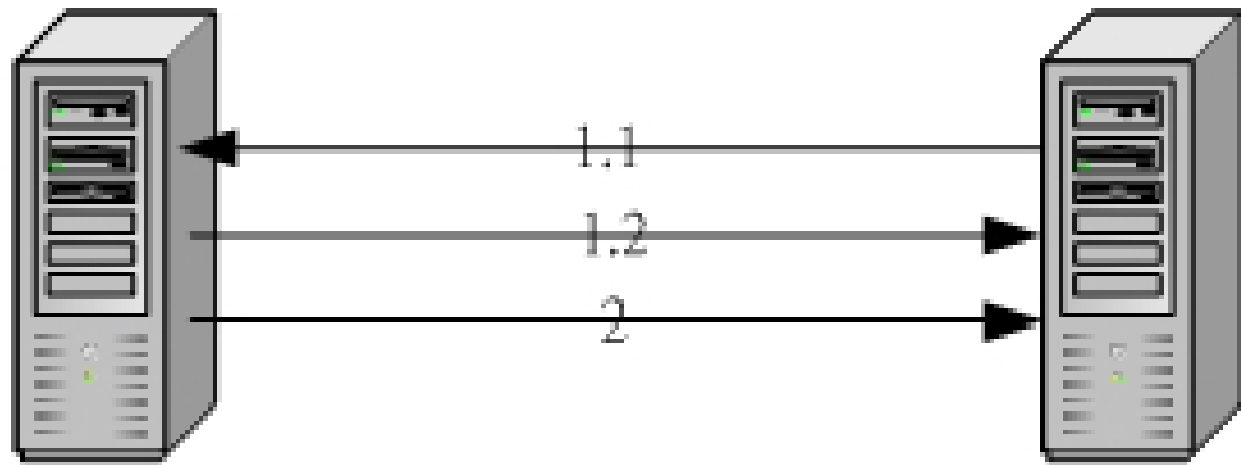
- What are the benefits of each?
- Which one is more reliable? Why?



# Key Issues

- Network access method (NAC), data link layer
  - Master/slave protocol (client/server)
    - An architecture in which one device (the master) controls one or more other devices (the slaves)
  - Peer-to-peer protocol (or P2P)
    - Each workstation has equivalent capabilities and responsibilities
    - Connection type (collision detection)
      - Used by Ethernet LAN standards
    - Token-passing type
      - Used by ACEnet

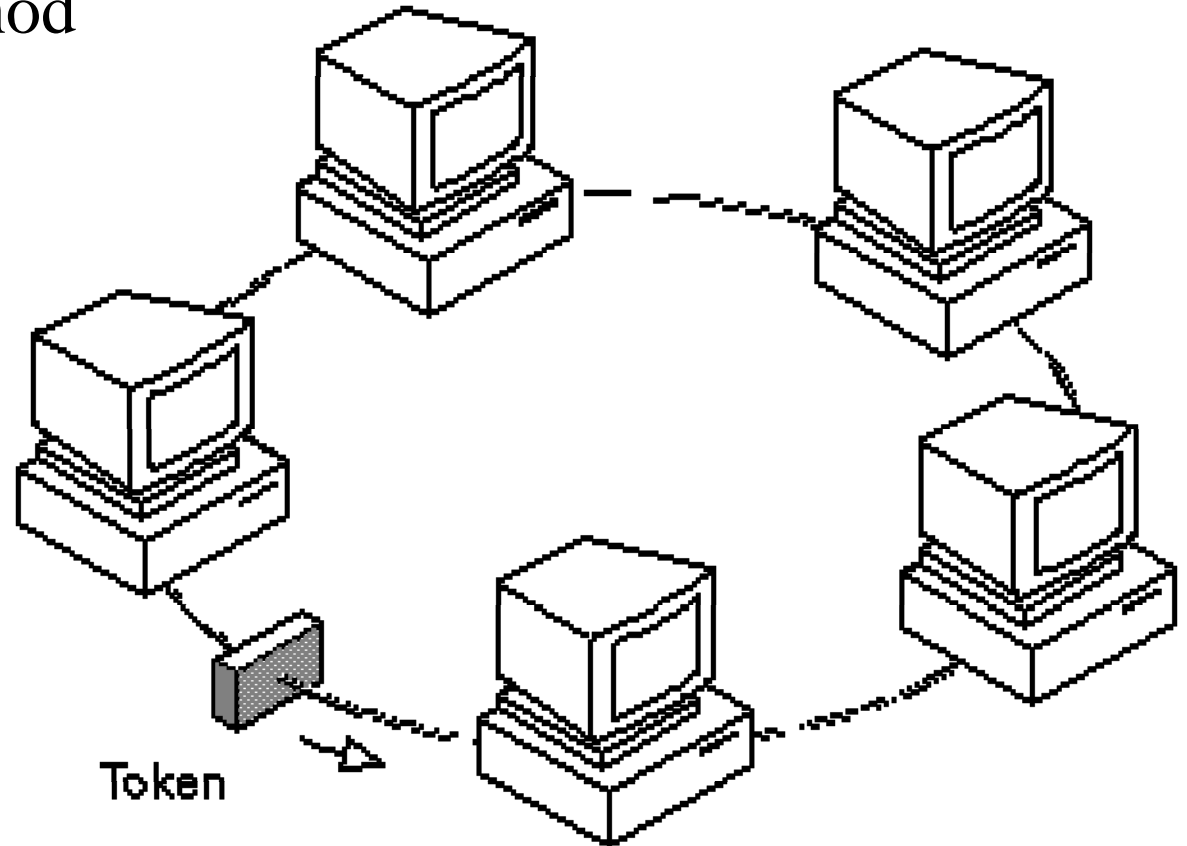




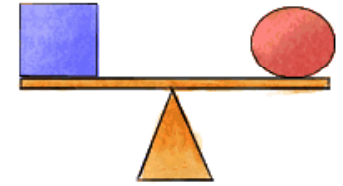
Master

Slave

Master-slave method



Peer-to-peer method token-passing type



# Key Issues

- LAN (local-area network) standards
  - Ethernet
    - ISO 8802-3 by Digital Equipment Corp., Intel Xerox
    - Peer-to-peer connection: e.g. carrier sense multiple access w/ collision detection (CSMA/CD)
    - Speed: 10 to 100 Mbps
  - ARCNET
    - Developed by Data Point Corp.
    - Star or bus topology, peer-to-peer token-passing
    - Speed: 2.5 Mbps

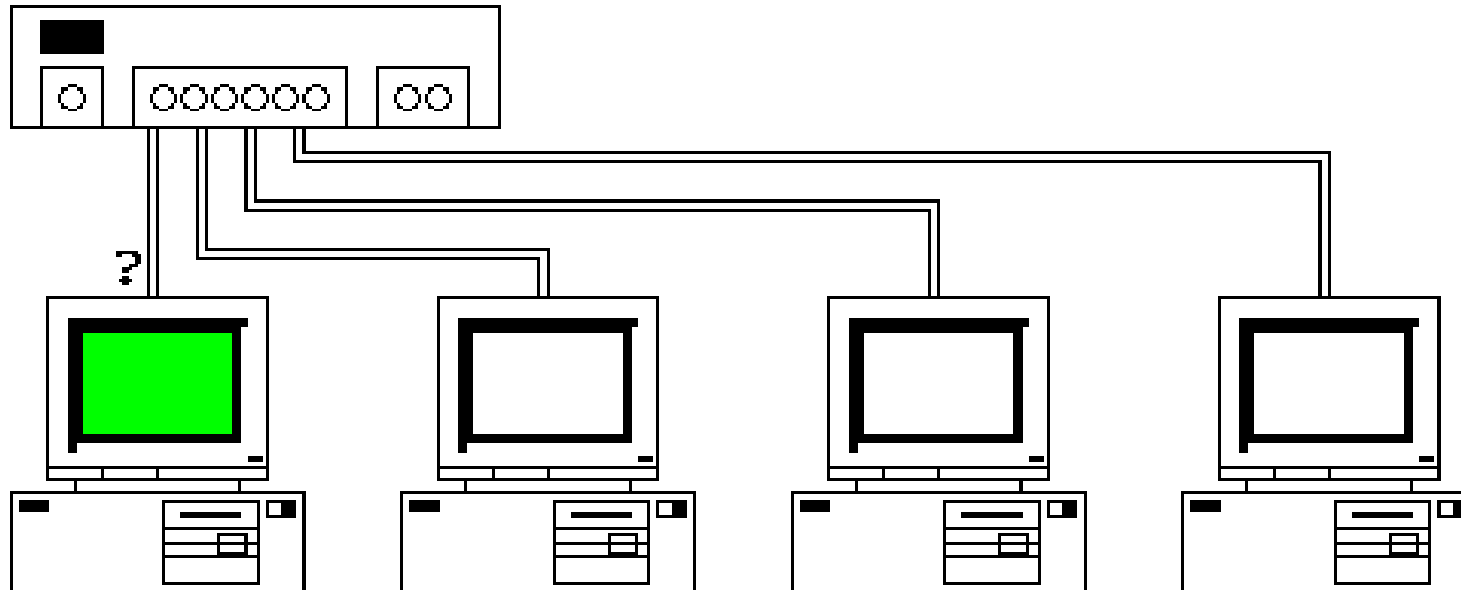
## Carrier Sense (CS):

Before a system can start transmitting on a Network, it 'listens' on the cable for a carrier signal (very much the same as when you pick up the phone and listen to the dial-tone). Only when the cable is not busy with another data-transfer, it will start the transmission.

## Multiple Access (MA):

As long as there is no 'busy-signal' on the cable, any connected station can start transmitting immediately.

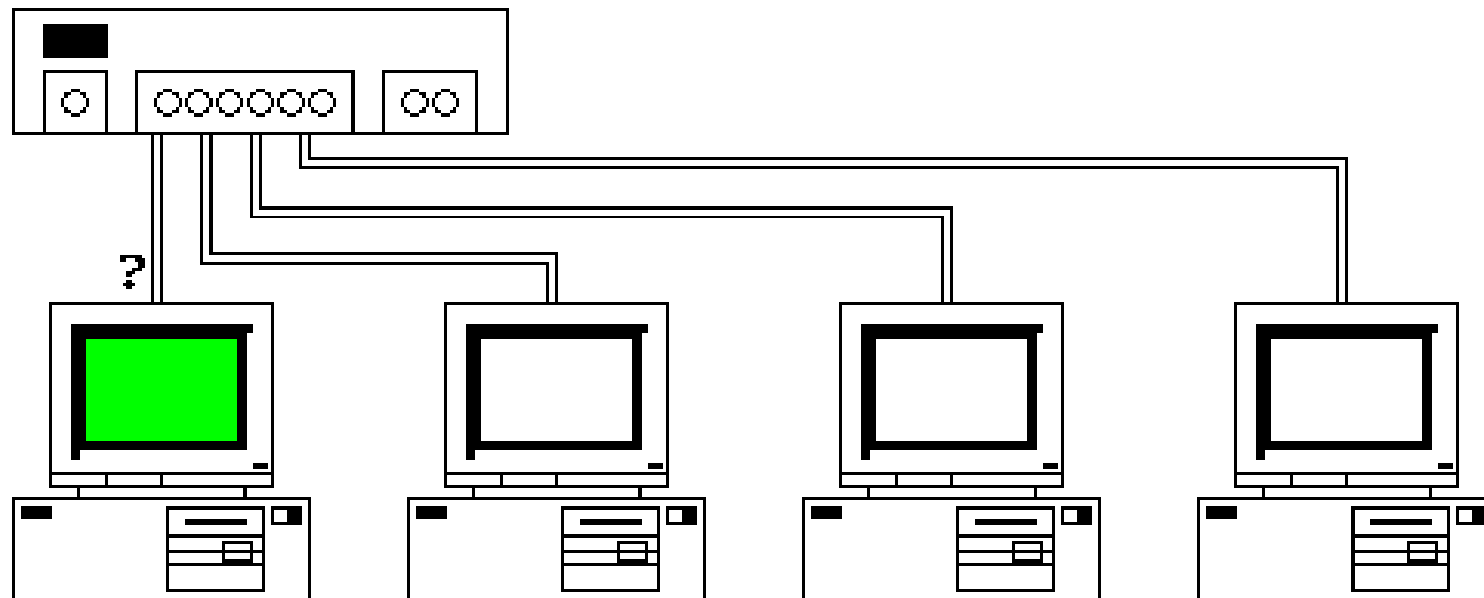
[www.WOWN.com](http://www.WOWN.com) Carrier Sense

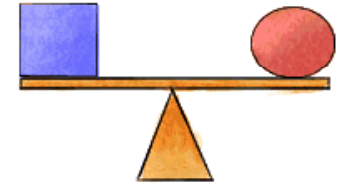


## Collision Detection (CD):

It can happen, that 2 or more stations start transmitting at the same time, which causes then a collision of the signal, which is then detected causing the transmitting systems to abort, wait a little (length is randomly determined) before the systems try to access the network cable again.

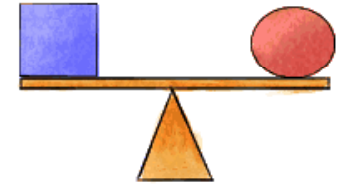
[www.WOWN.com](http://www.WOWN.com) Carrier Sense





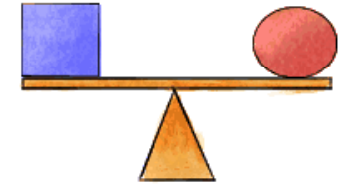
# Key Issues

- Physical layer standards
  - For data transfer between components
  - Three common standards:
    - Electronic Industries Associations Standard EIA-232 or RS-232 (RS = recommended standard)
      - Up to 20 Kbps; max. 15 m wiring
    - EIA-485 or RS-485
      - Three wire, polarity-sensitive transceiver
    - FTT: Free Topology Transceiver
      - Two-wire, unshielded, polarity insensitive transceiver



# Key Issues

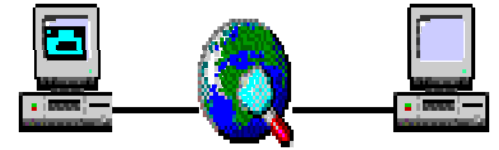
- Physical media
  - Twisted pairs (TP)
  - Twisted shielded pairs (TSP)
  - Coaxial cable
  - Fibre optic cables
  - Power line carrier (PLC)
    - Rarely used in HVAC DDC because of noise & speed
- (\* More info in the “*Networking*” lecture)



# Key Issues

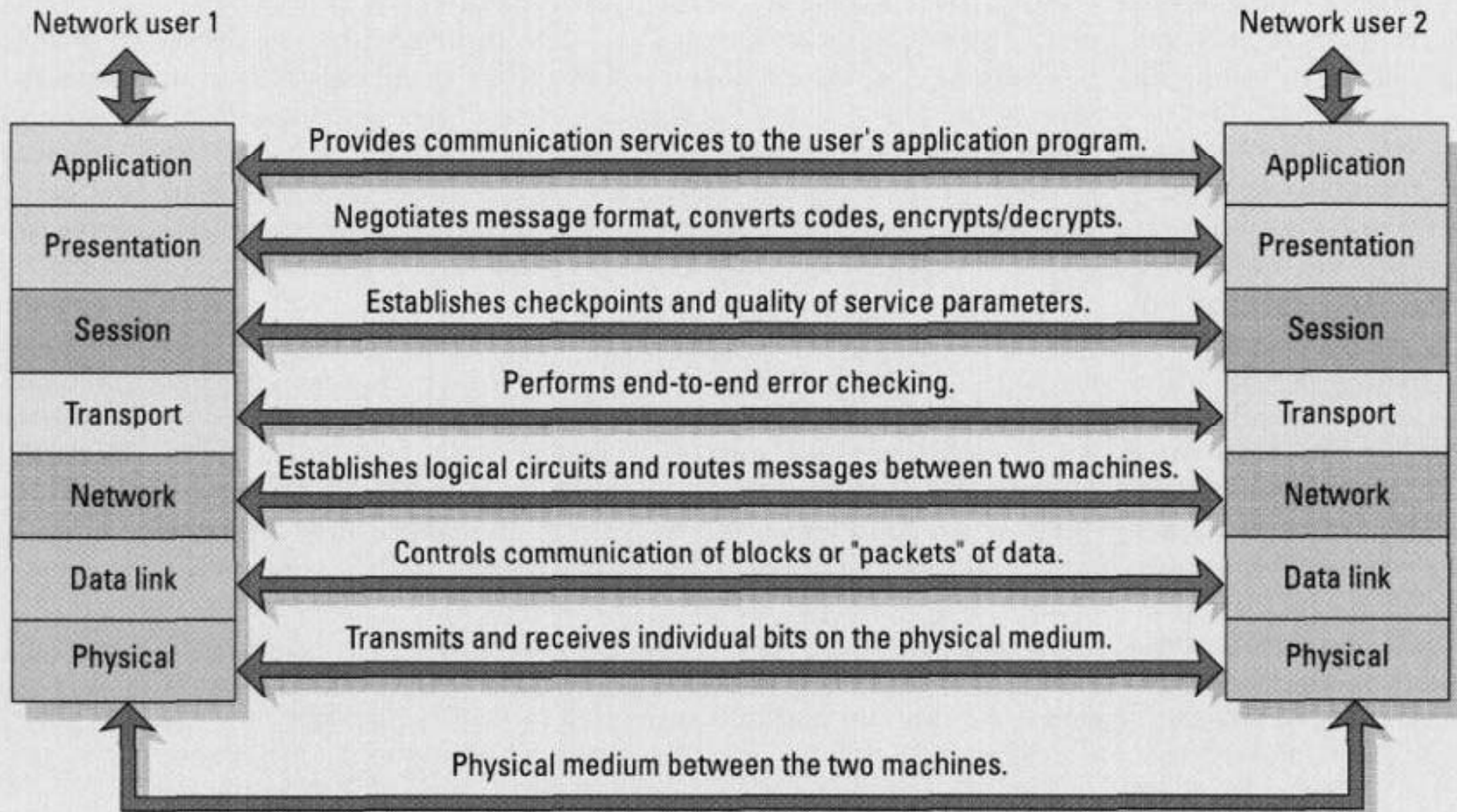
- Examples:
- **DDC Online** [<http://www.ddc-online.org/>]
- Architecture diagrams, e.g.
  - Honeywell: Excel 5000
  - Johnson Controls: Metasys M-Series
  - Siemens APOGEE
  - Solidyne: IZAC Control and Monitoring System
- Product details

# Interoperability



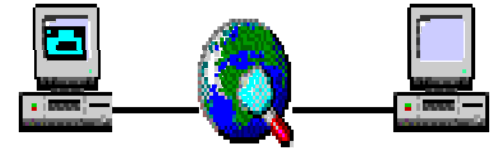
- Definitions
  - The ability of software and hardware on different machines from different vendors to share data. [wedopedia.com]
  - The ability of two or more systems or components to exchange information and to use the information that has been exchanged [from IEEE]
  - The ability of equipment to work together & communicate mutually [see journal article in references]
    - Between different manufacturers' control equipment
    - Different versions of control equipment
    - Equipment for different purposes (HVAC, fire, lights)



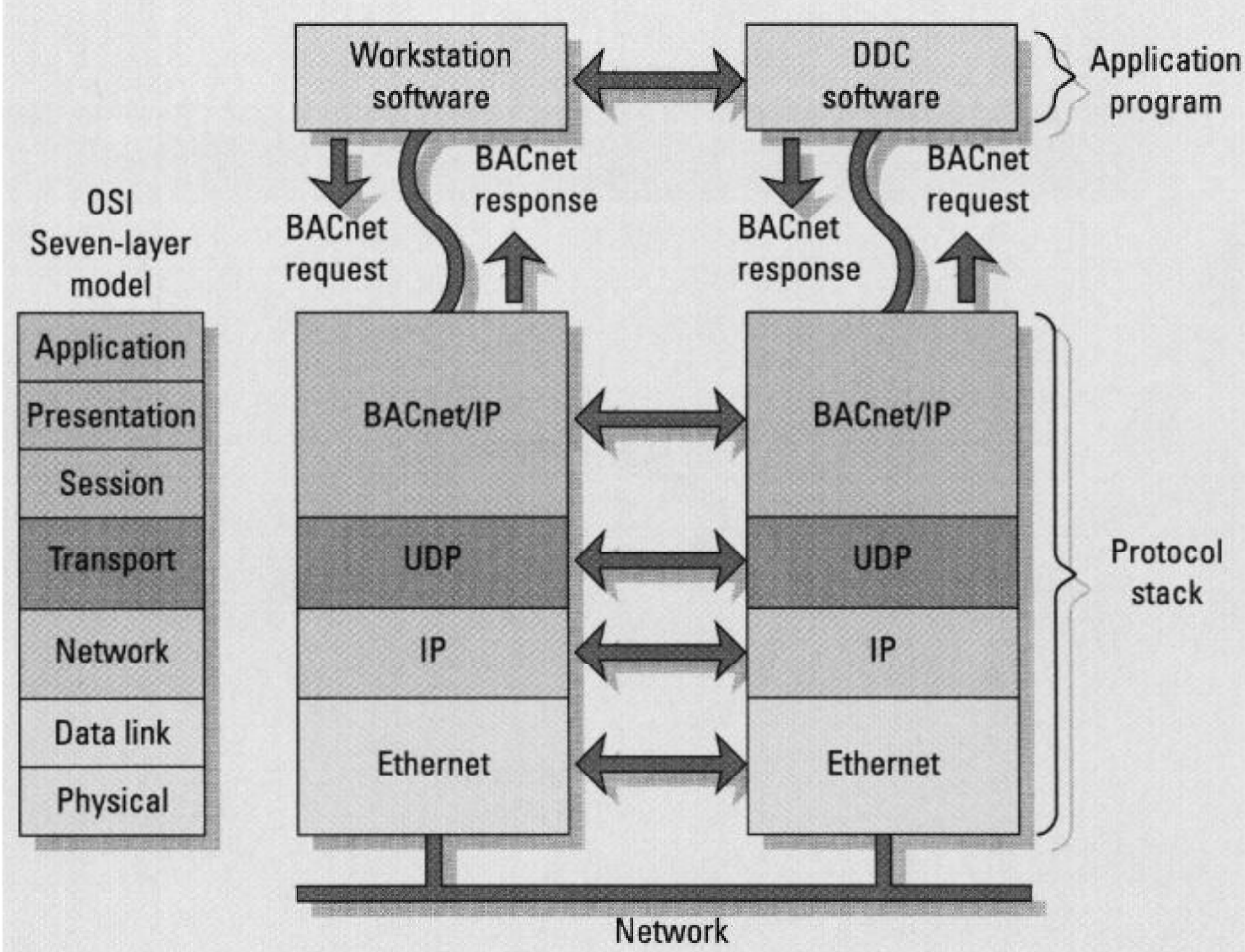


**FIGURE 2. The ISO/OSI Seven-Layer Model arranges communication functions into seven groups or "layers." Each layer provides services locally to the layer above while communicating with its peer layer in the remote device. Protocols that implement the model need only select the functions needed for the application at hand.**

# Interoperability

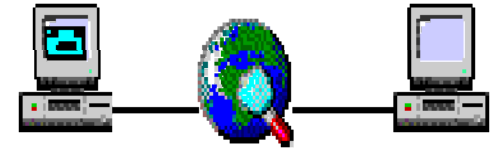


- Building automation example
  - Protocol ‘stack’:
    - BACnet/IP
    - UDP (User Datagram Protocol)
    - IP (Internet Protocol)
    - Ethernet
  - Data communication
    - Horizontal bi-directional (conceptual)
    - Vertical procedure: BACnet request & response
      - User UDP software
      - Protocol control information (PCI) is added

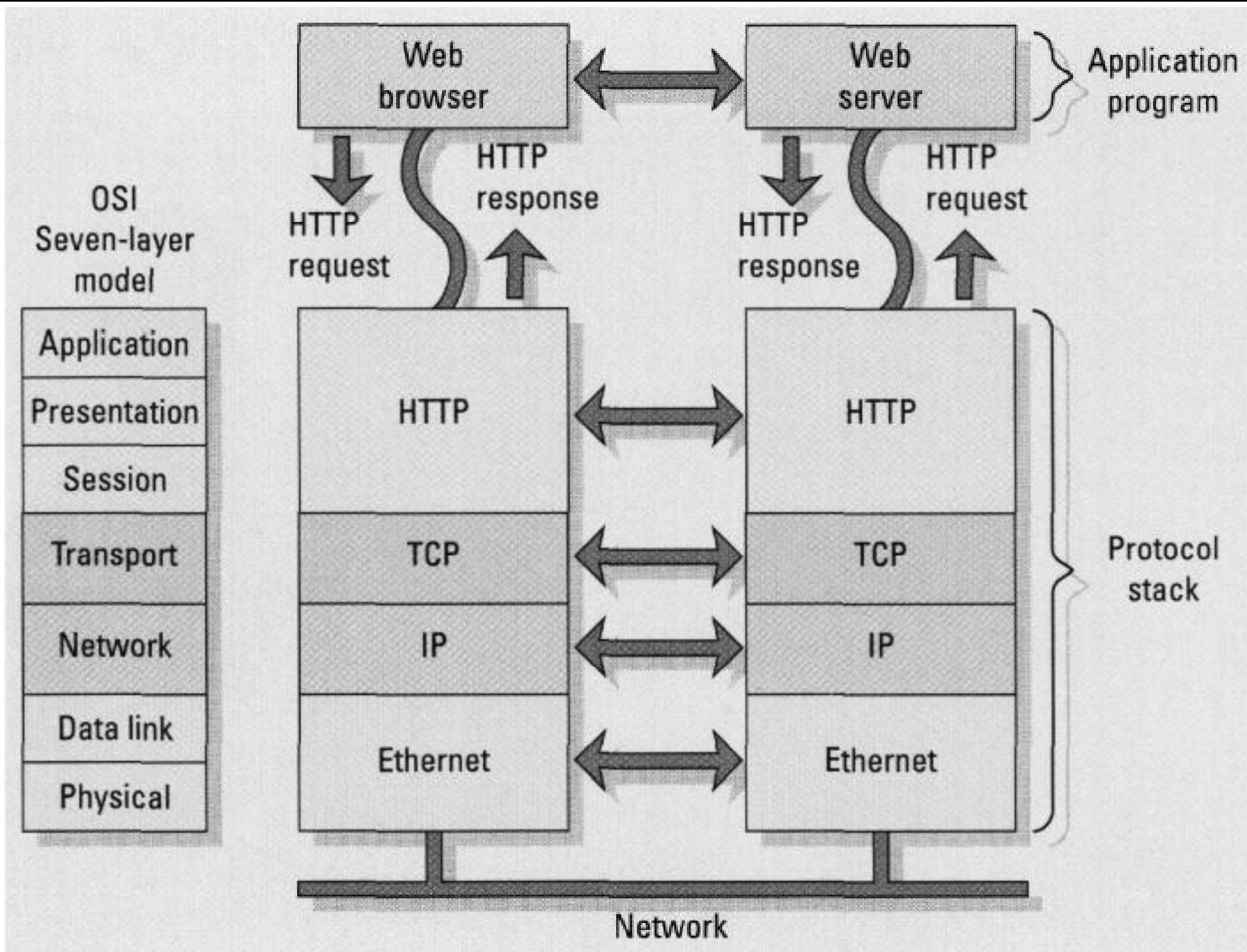


(Source: Newman, H. M., 2001. Control networks and interoperability, *Network Controls*, May 2001, pp. 17-27.)

# Interoperability

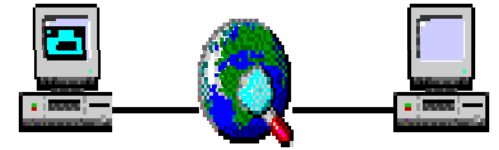


- Web browsing example
  - Protocol ‘stack’:
    - HTTP (Hypertext Transfer Protocol)
    - TCP (Transmission Control Protocol)
    - IP (Internet Protocol)
    - Ethernet
  - Data communication
    - Horizontal (Web browser & Web server)
    - Vertical procedure: HTTP request & response

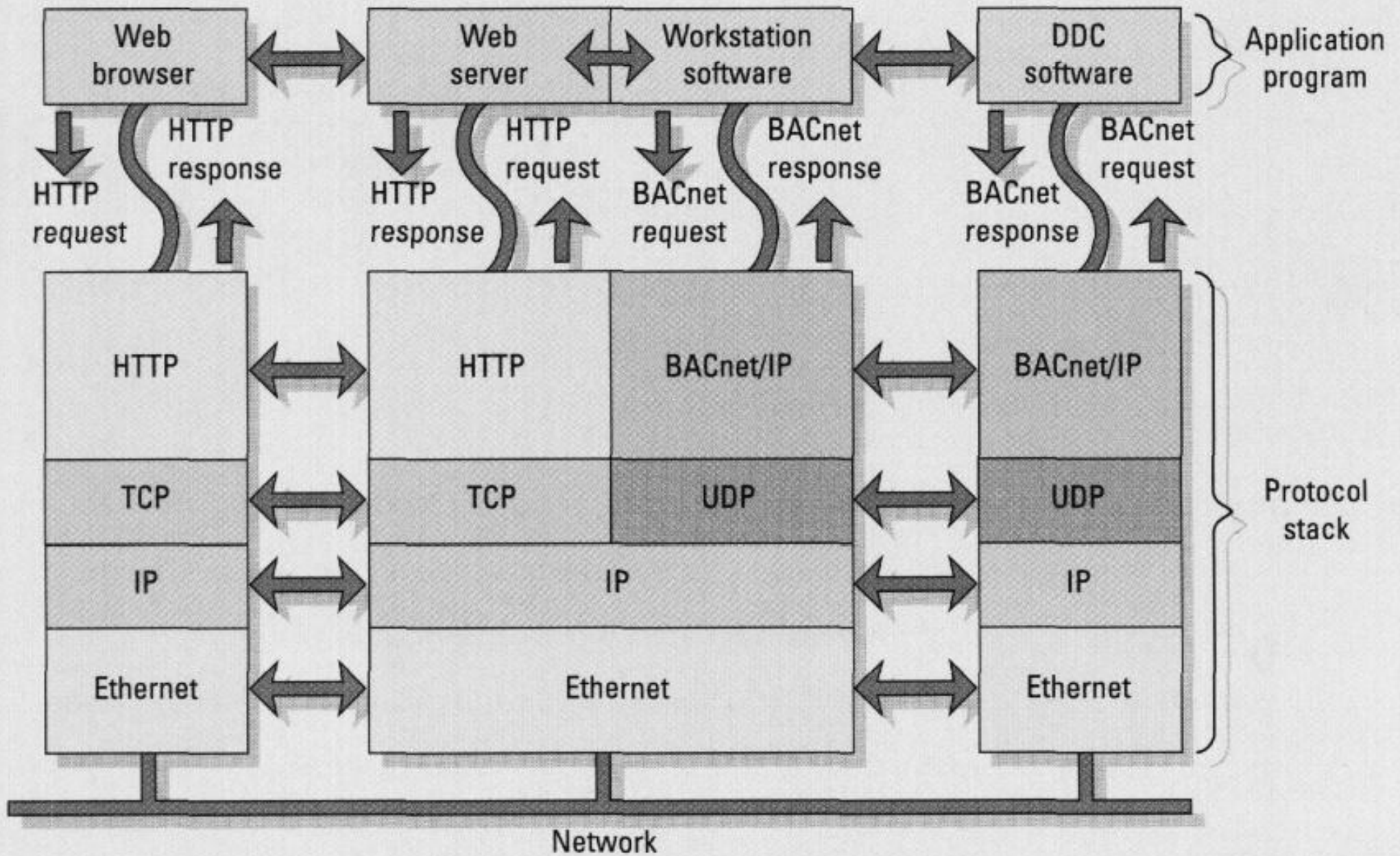


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# Interoperability

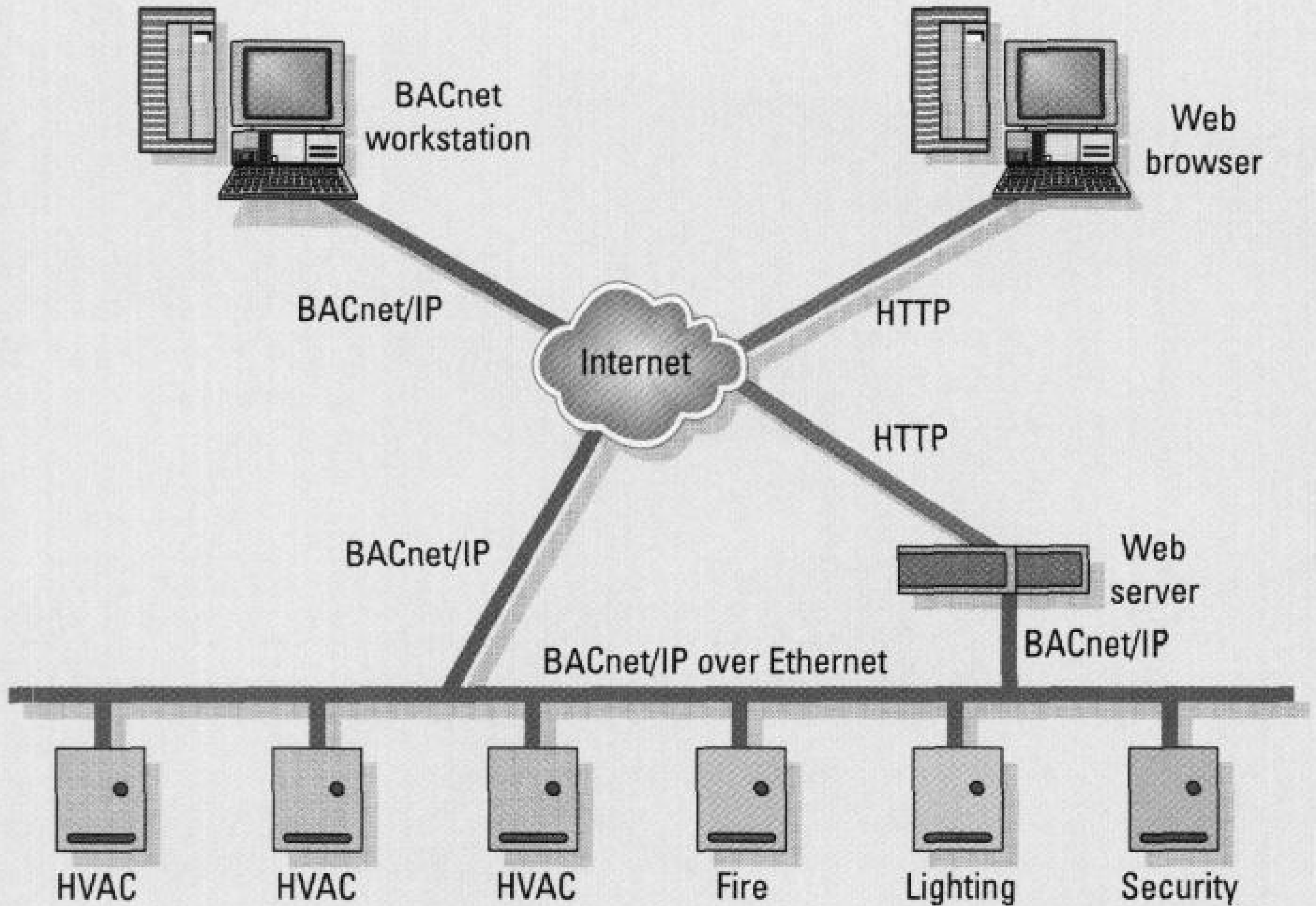


- Web browser as control system workstation
  - Any PC with a Web browser can be used
  - Web server/control system gateway
    - Web server -> Workstation software (proprietary)
    - Data in HTML format for display at Web browser



**FIGURE 6. A Web browser that accesses an appropriately programmed Web server can perform the same kind of functions as the dedicated workstation in Figure 3.**

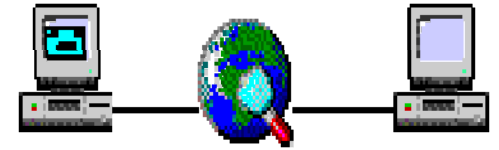
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# Interoperability



- Designing interoperable systems
  - Define the application (which system, what data)
  - Select equipment that performs the desired functions & supports a common protocol
  - For equipment that does not supports common protocol directly, add gateways or relays
  - Determine operator-machine interface (OMI): workstation, Web server gateway
  - Ensure the contractor understand the network architecture well



# BAS Case Study

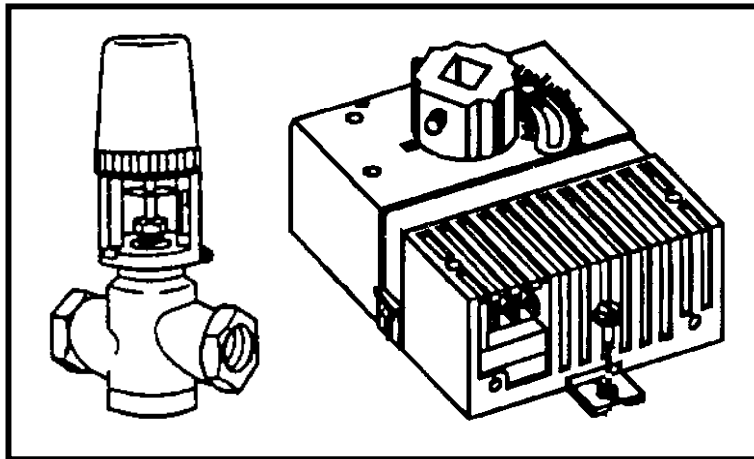
- System architecture
- Major components
- Access levels
- Network map & graphic presentation
- Common BAS functions

[\* Acknowledgement: to Johnson Controls (HK)]

# Building Automation System

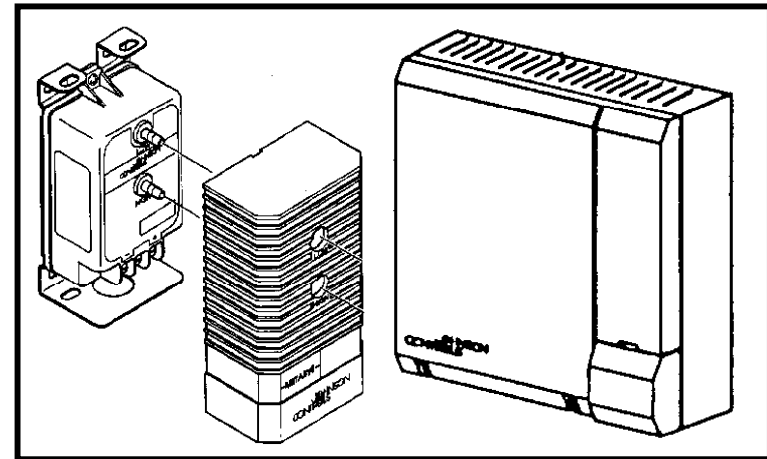
## Actuators

Position dampers and valves based on electronic signals

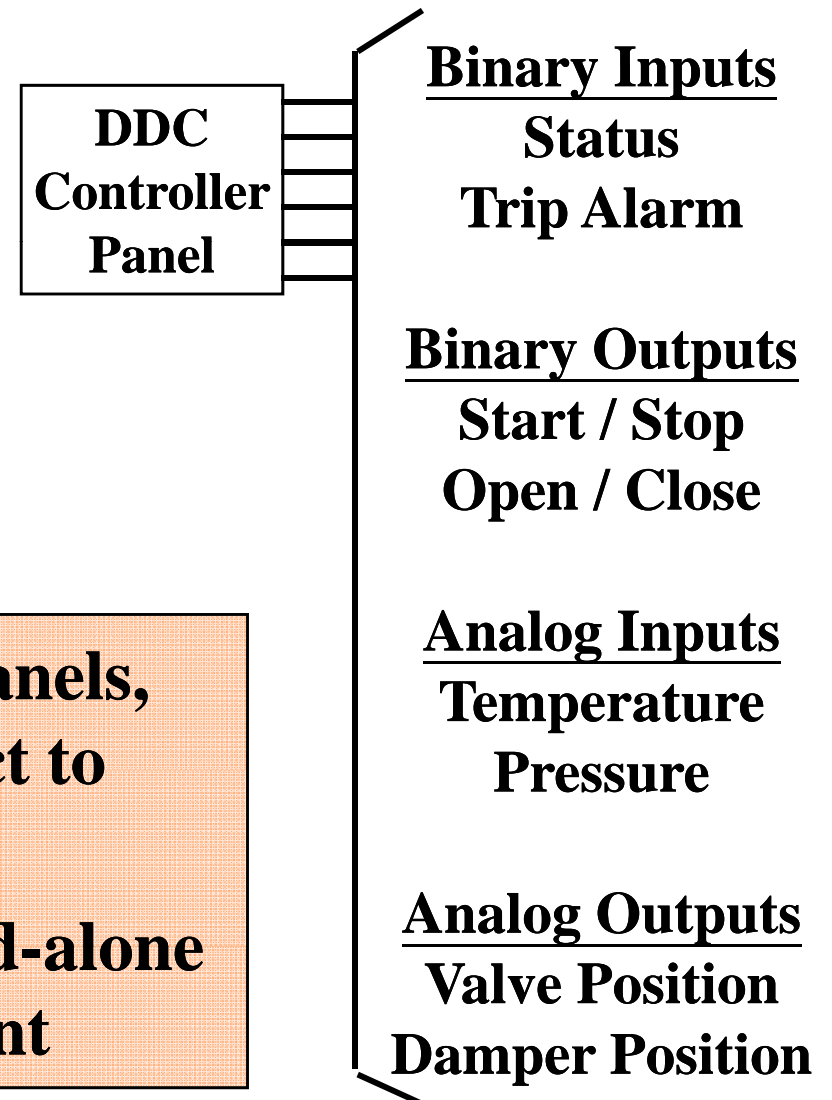


## Sensors

Convert physical conditions into electronic signals



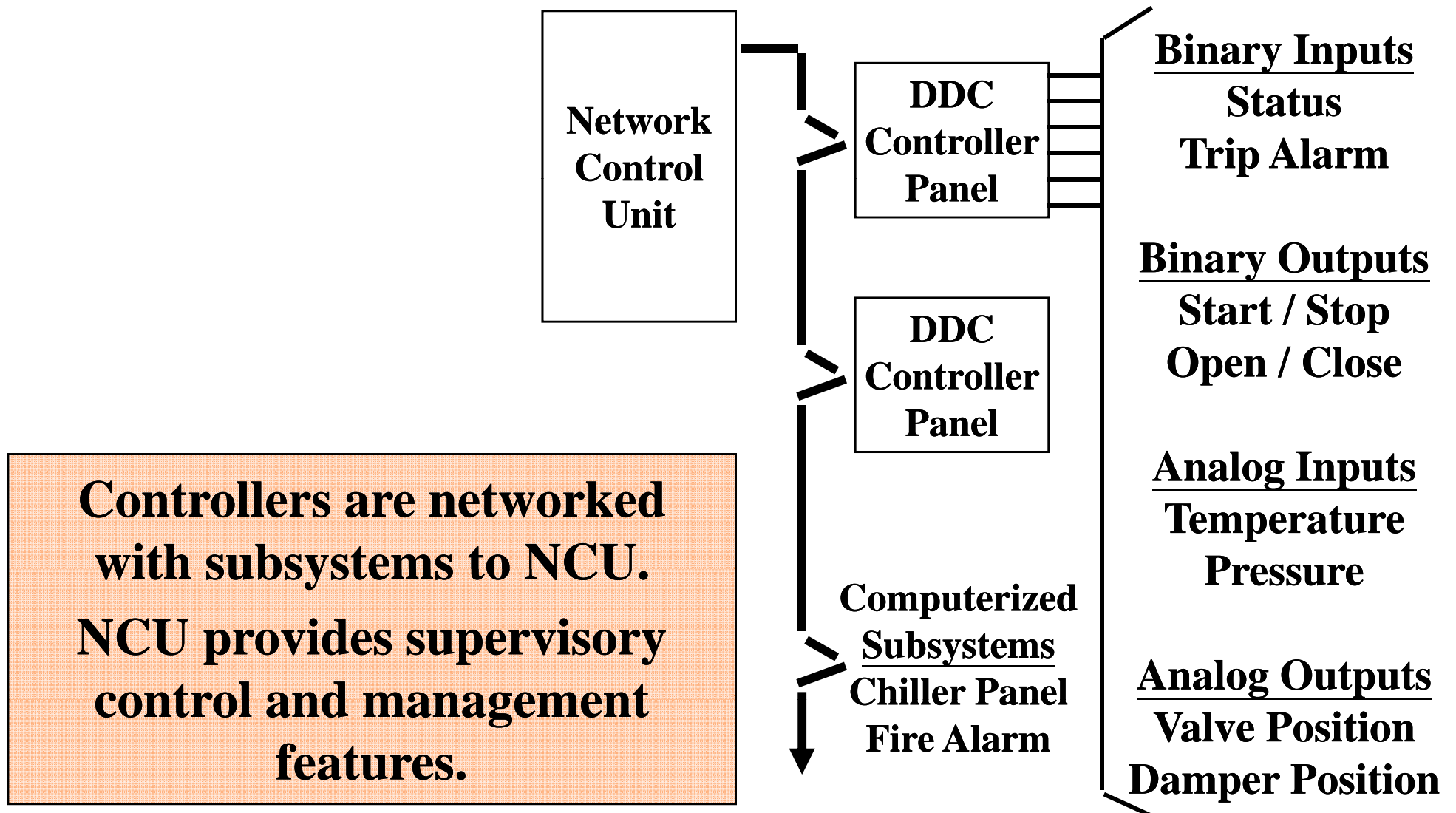
# Building Automation System



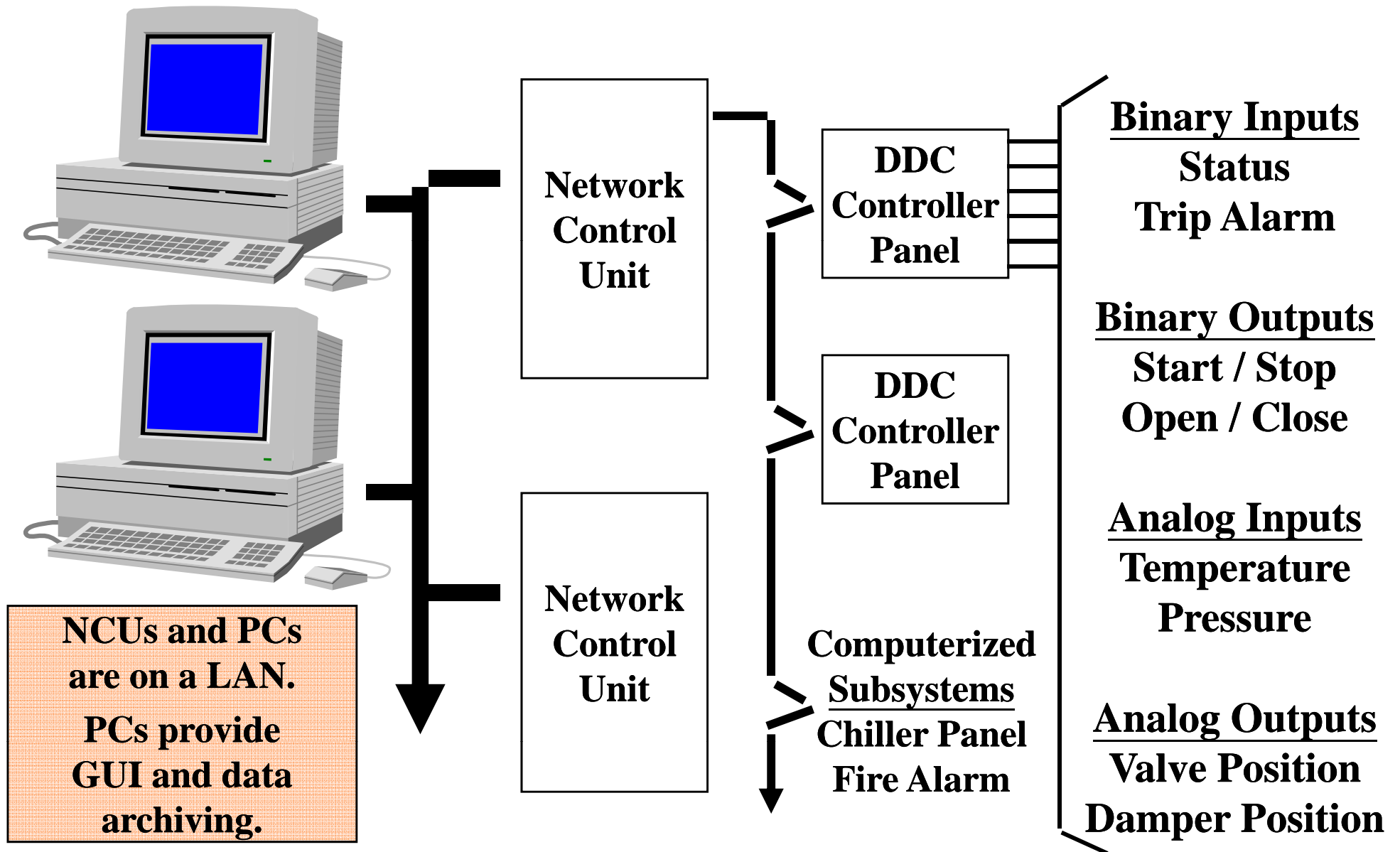
**Wiring from equipment control panels, sensors and actuators are connect to DDC Controllers.**

**DDC Controllers provide local stand-alone control to maintain environment**

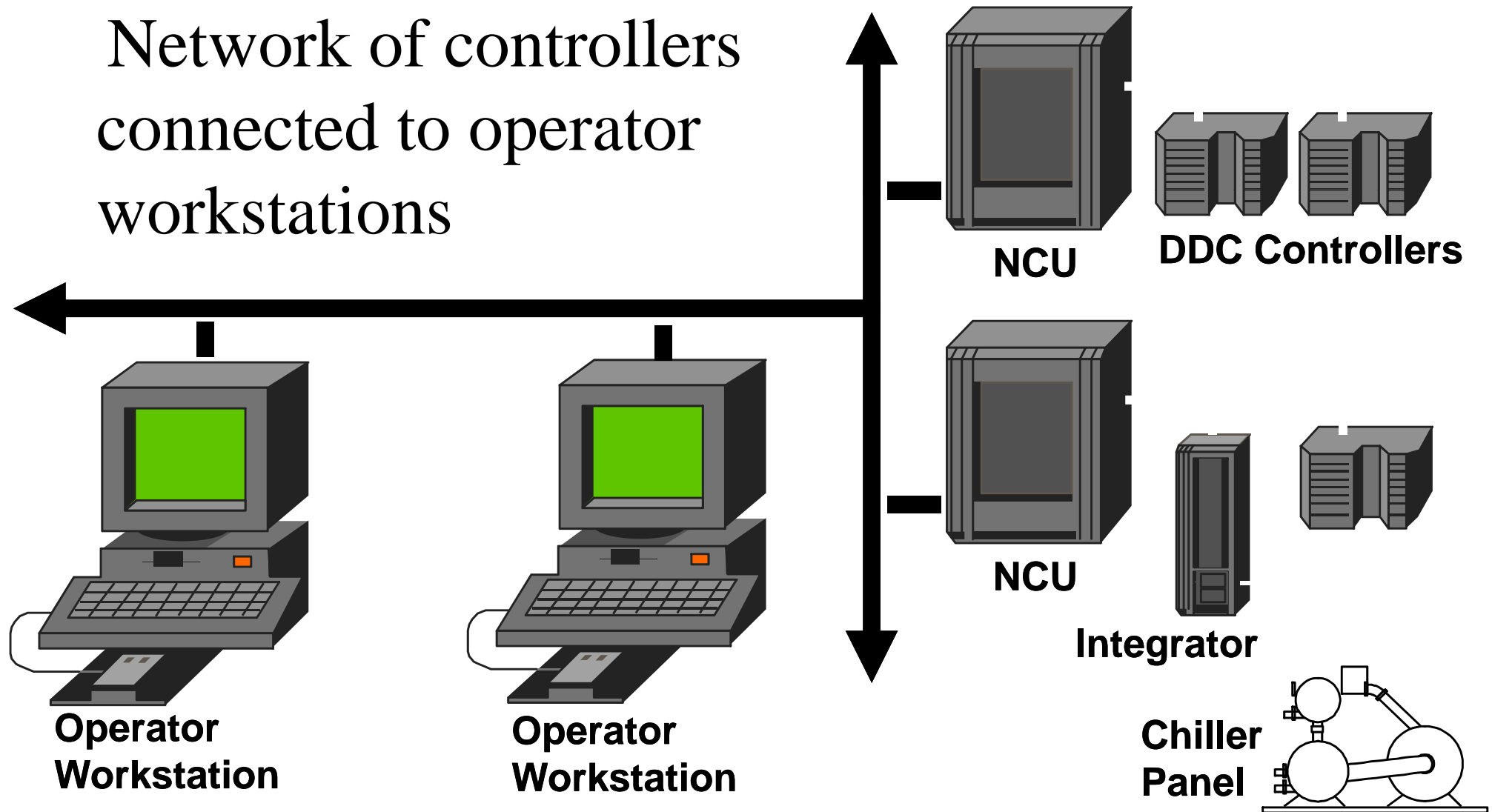
# Building Automation System



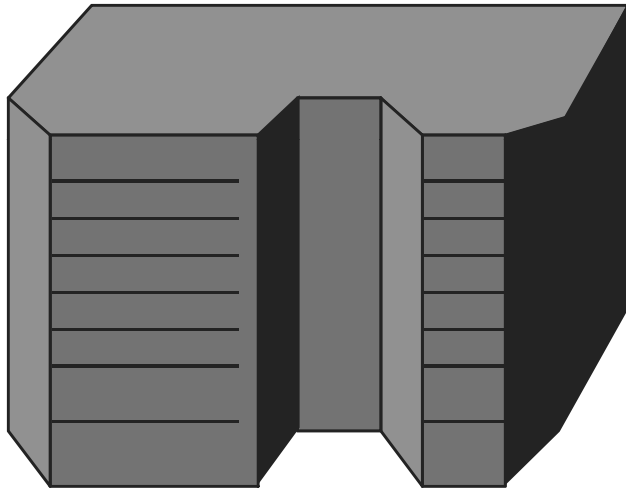
# Building Automation System



# Building Automation System



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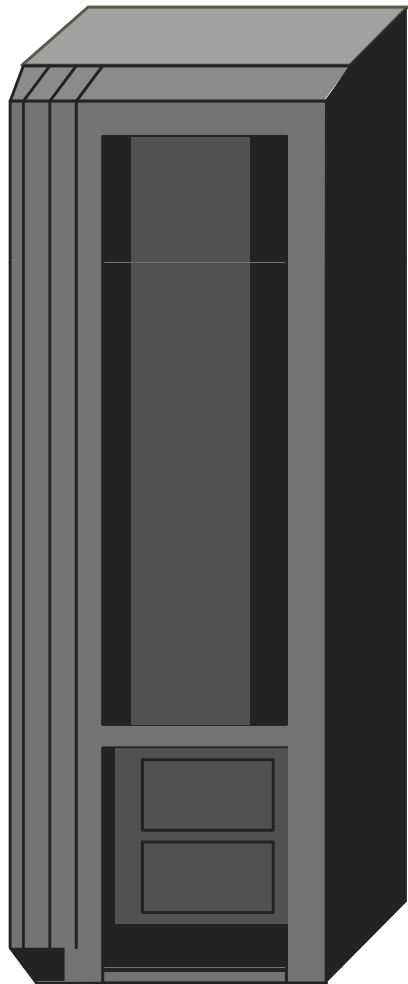


## DDC Controllers

- Located in risers and mechanical rooms
- Connect to inputs and outputs on M&E equipment
- Stand alone control operation



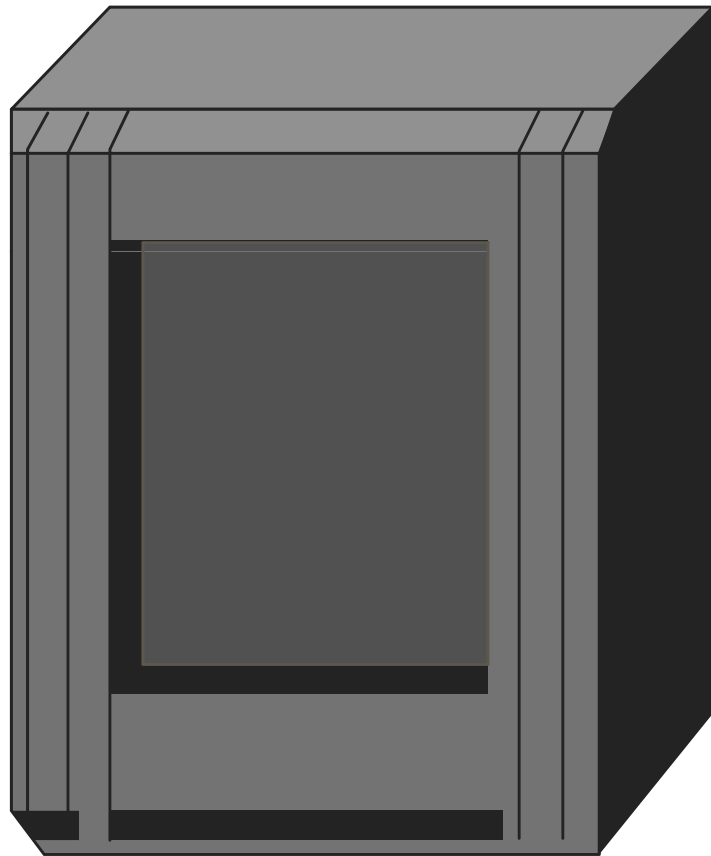
# Building Automation System



## Integrator

- Connects to factory mounted  $\mu$ P based controls
  - Chiller
  - CRAU
  - Fire Alarm System
  - etc..

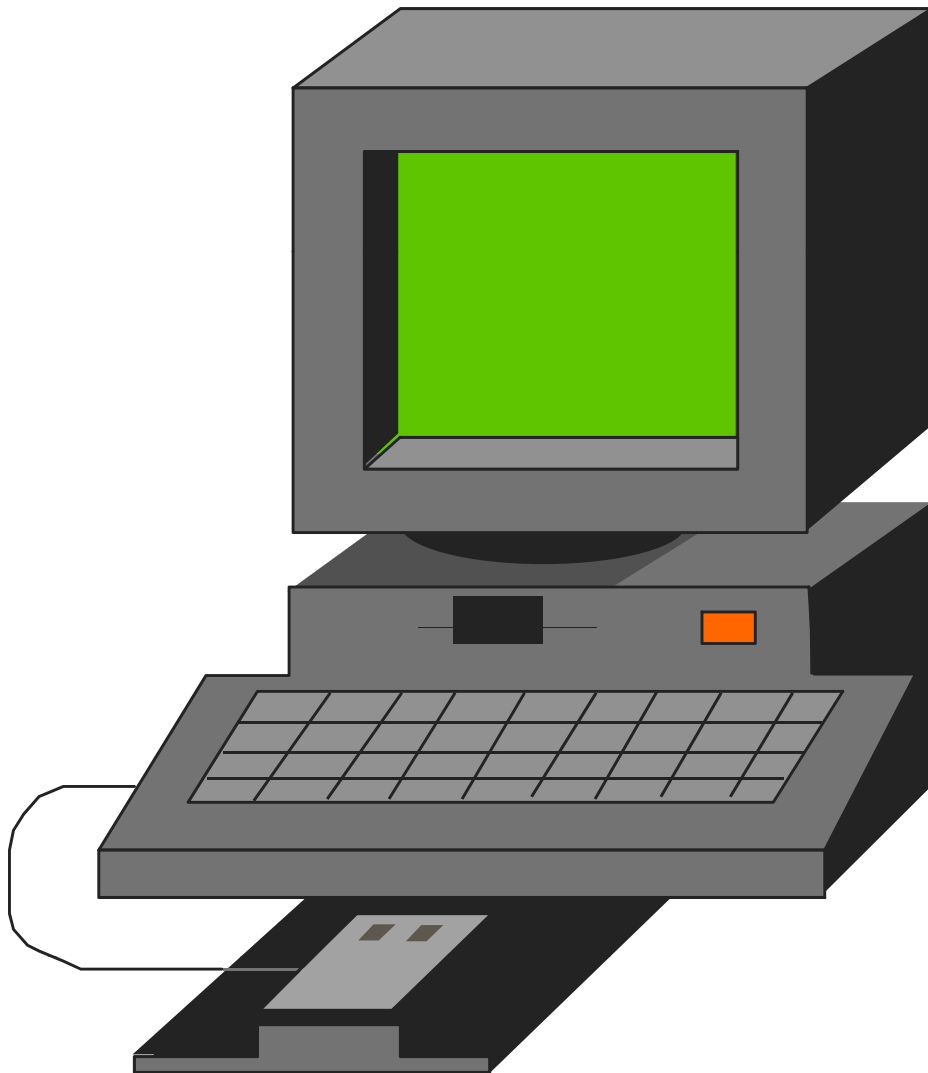
# Building Automation System



## Network Control Unit

- Performs BAS features
- Stores active database
- Global strategies

# Building Automation System

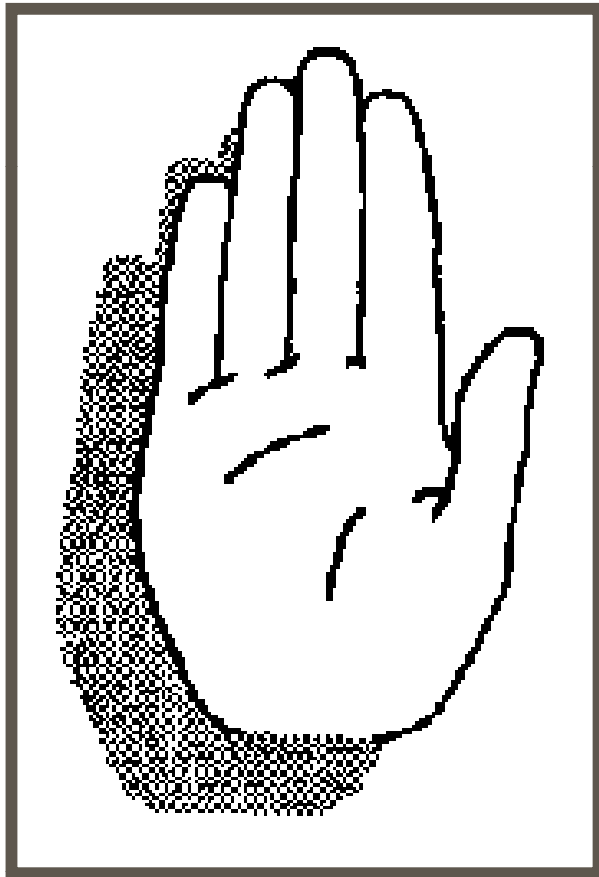


## Operator Workstation

- IBM compatible PC
- Graphical user interface
- Long term data storage

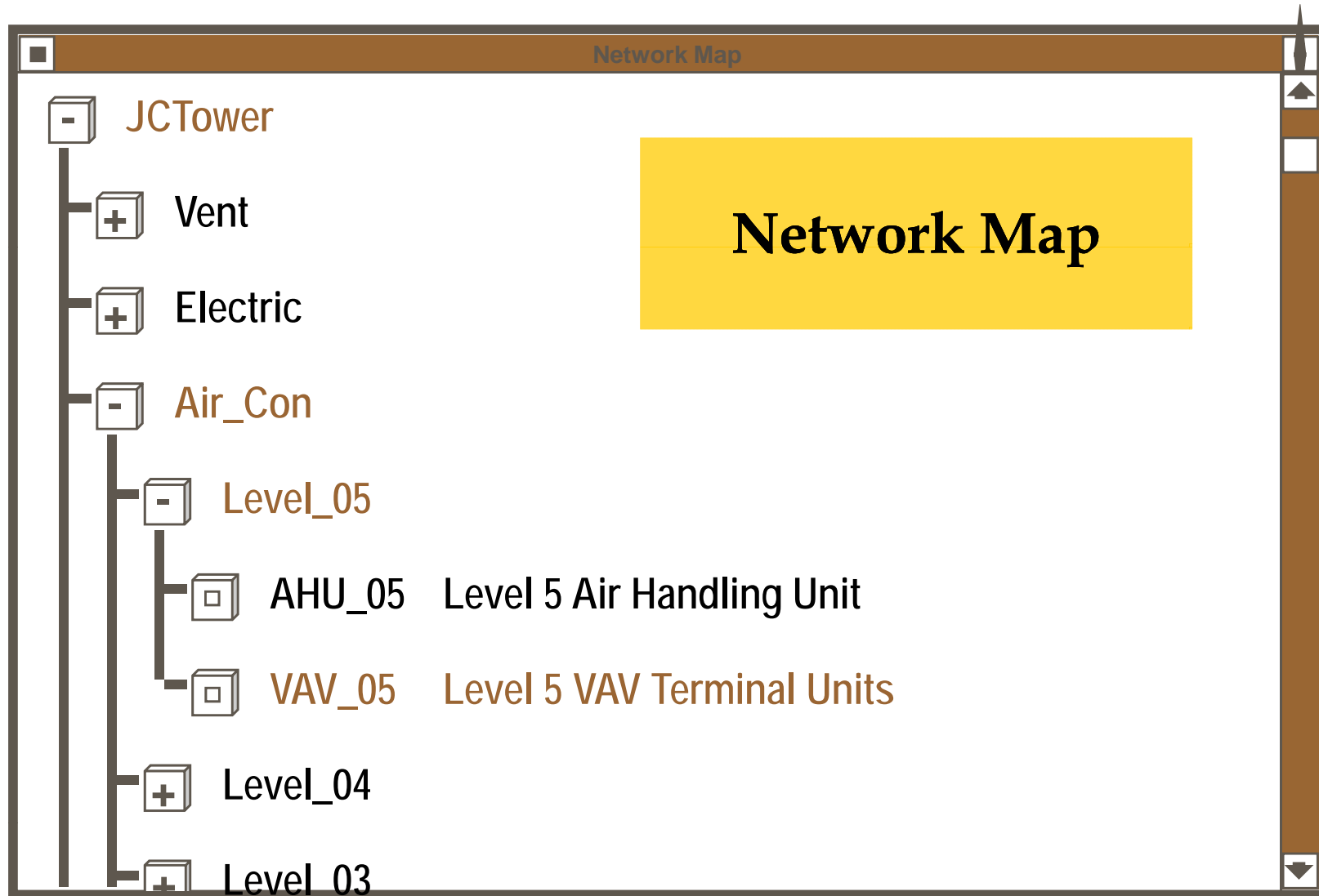
# Building Automation System

## *Password*

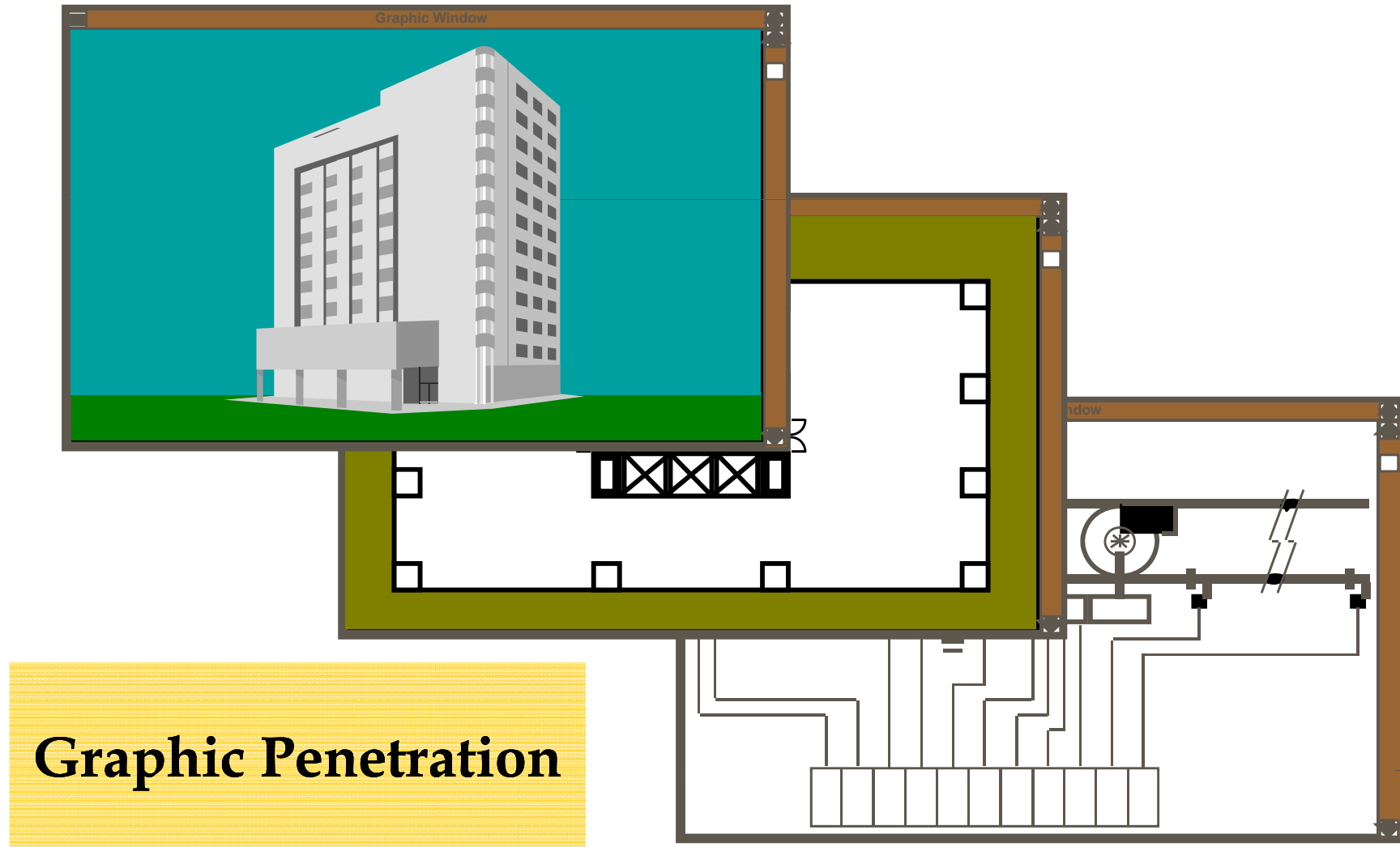


- Limits system access
- 5 levels of access
- Audit trail of operator activity

# Building Automation System

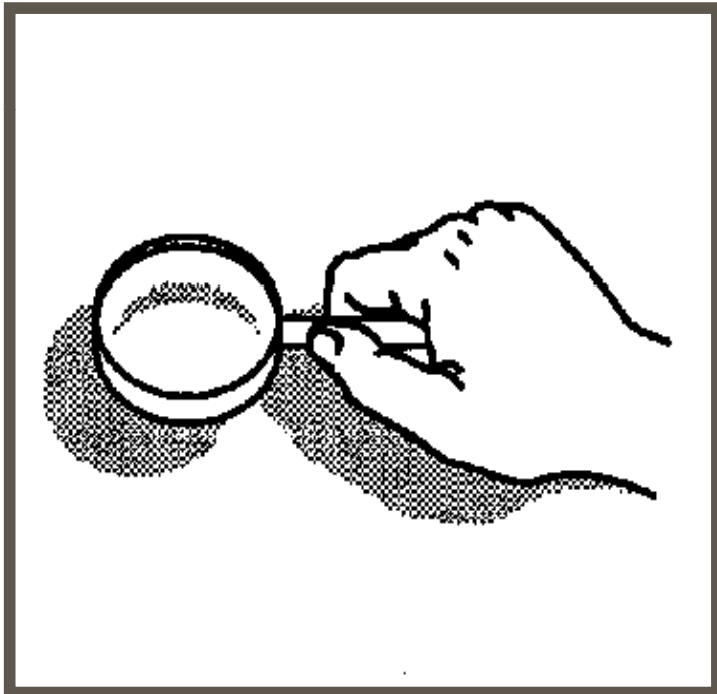


# Building Automation System



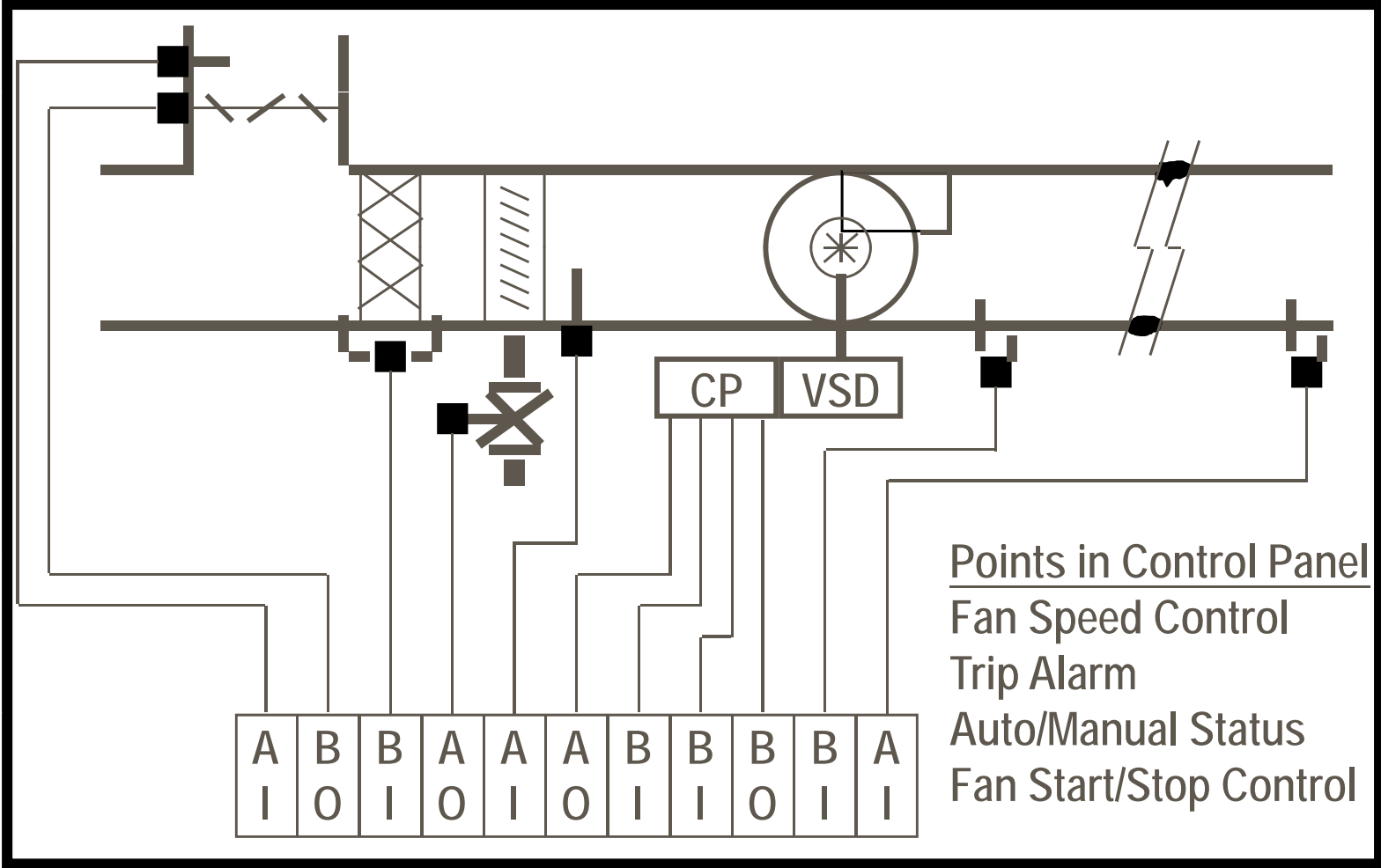
# Building Automation System

## *Point Focus*



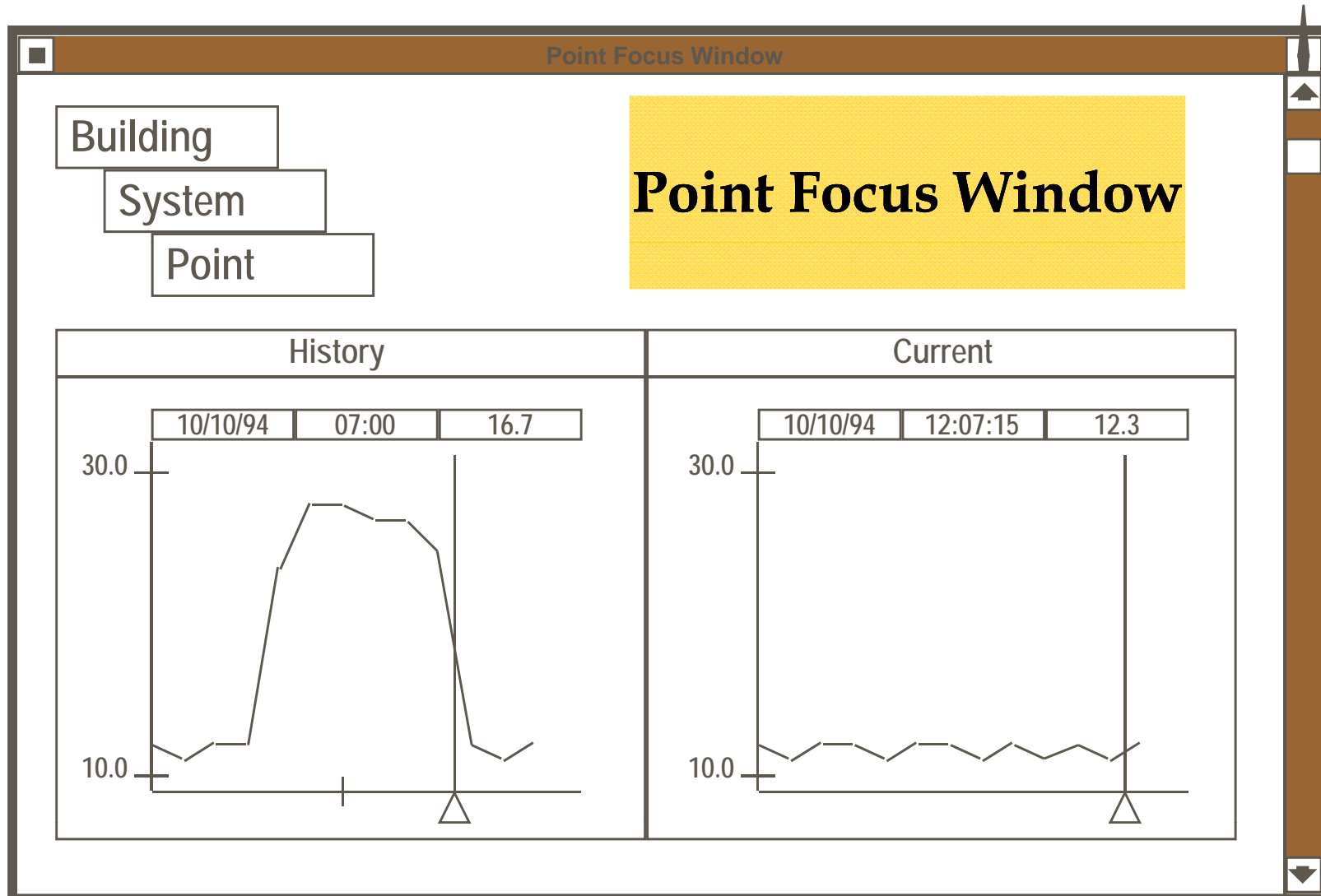
- All information in a single summary for quick analysis
- Historical and real-time data so that operator has the complete picture

# Building Automation System

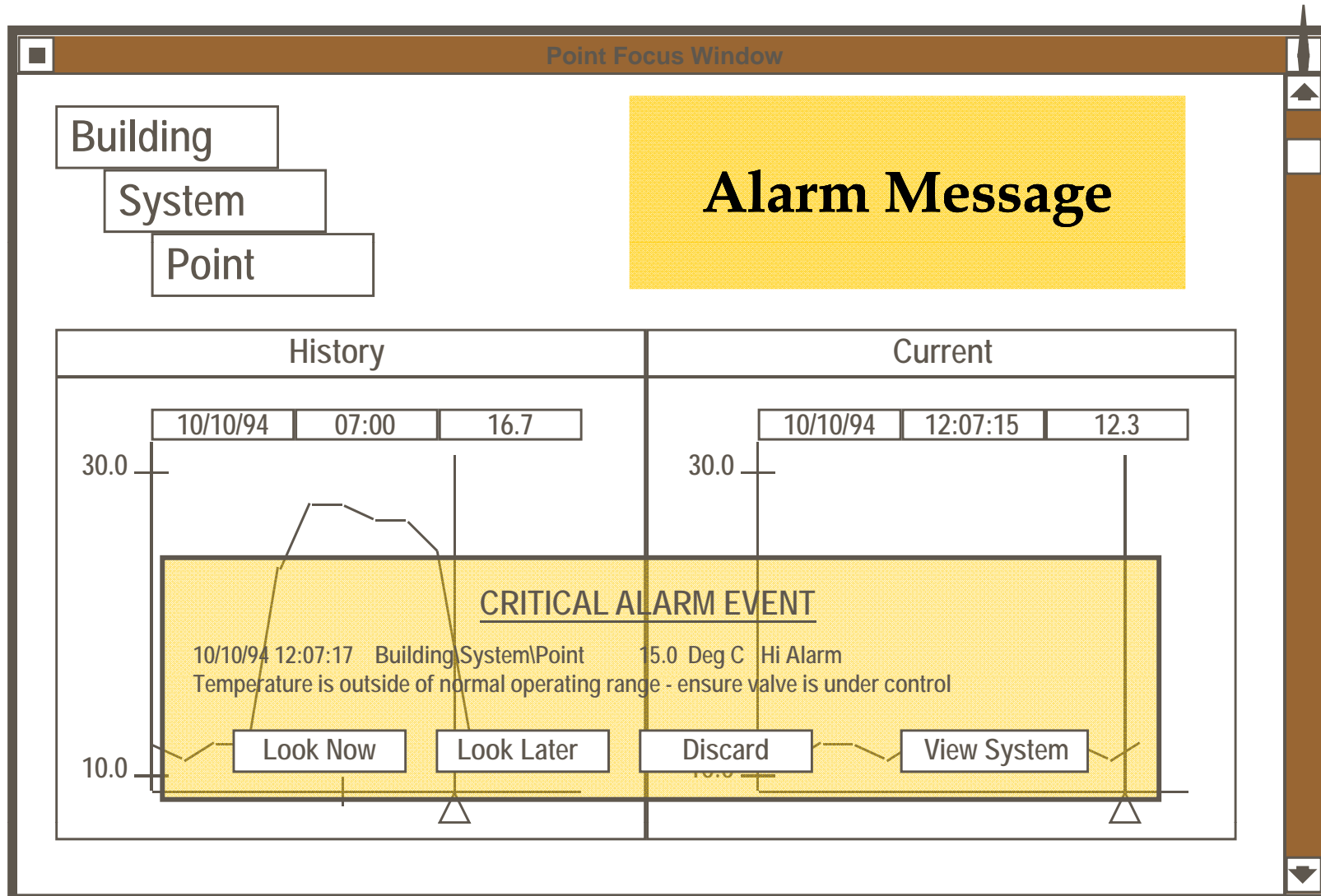




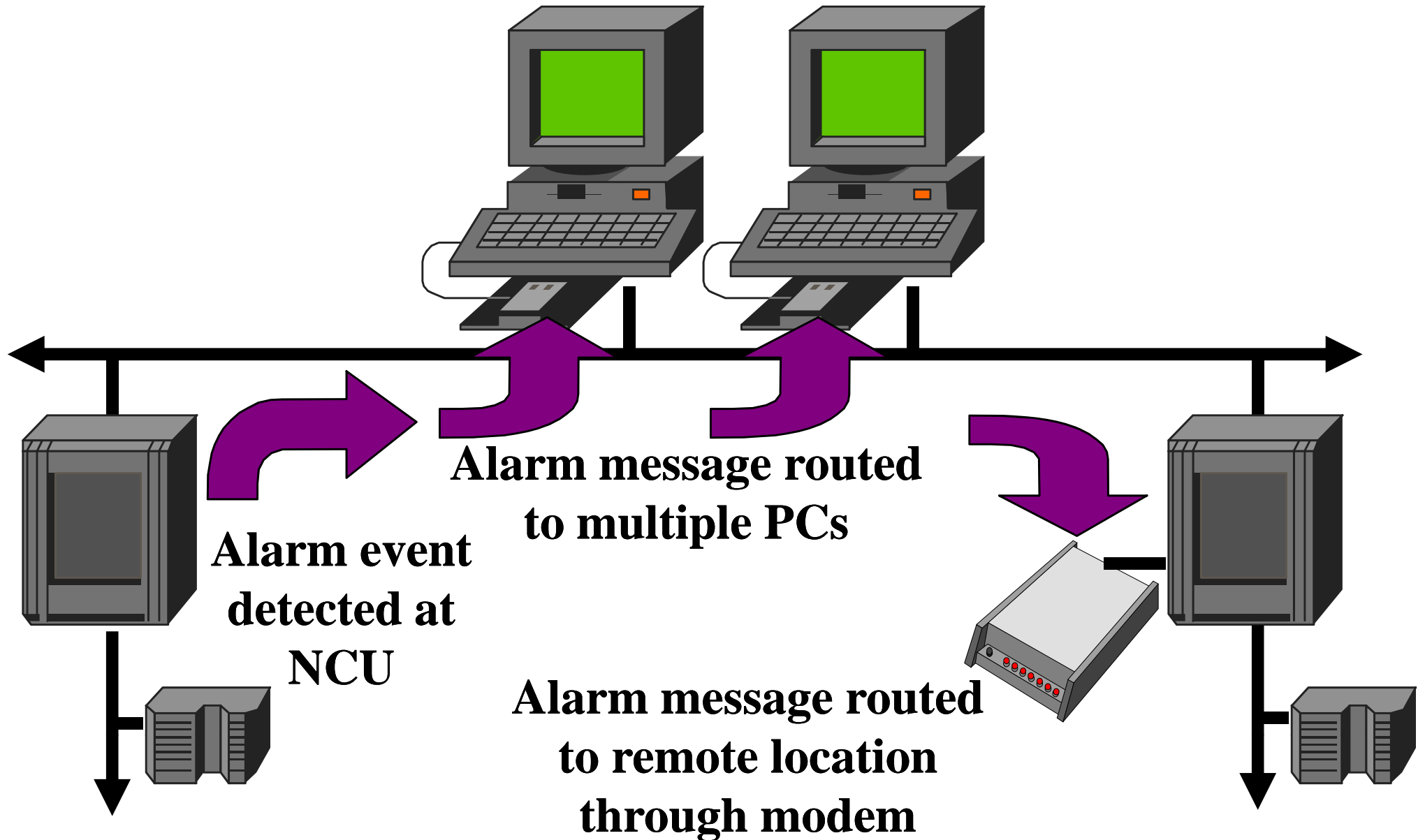
# Building Automation System



# Building Automation System

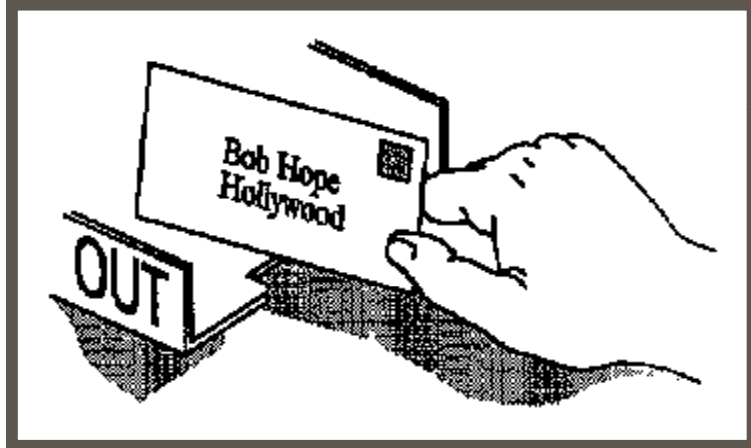


# Building Automation System



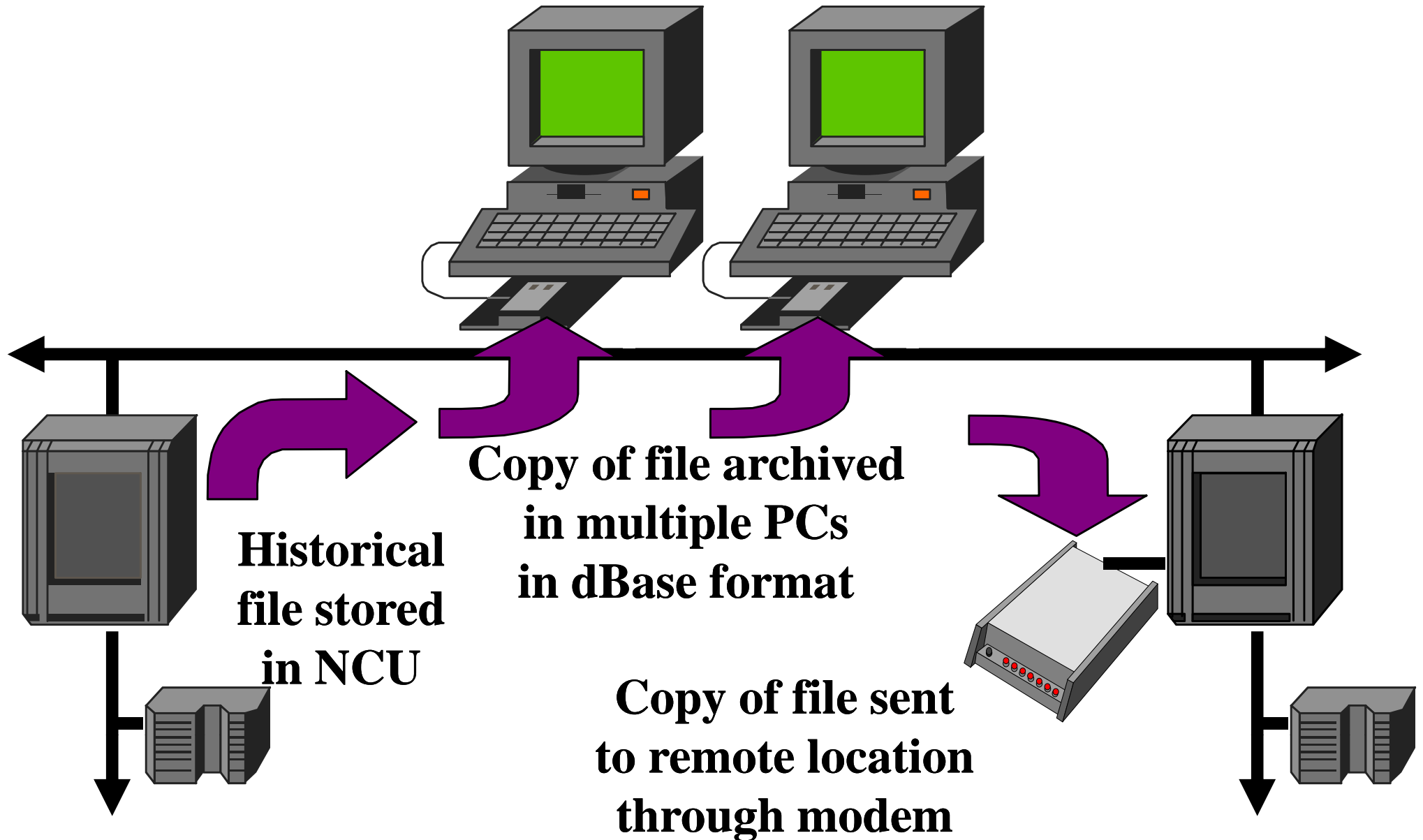
# Building Automation System

## *Report Routing / Alarm Management*



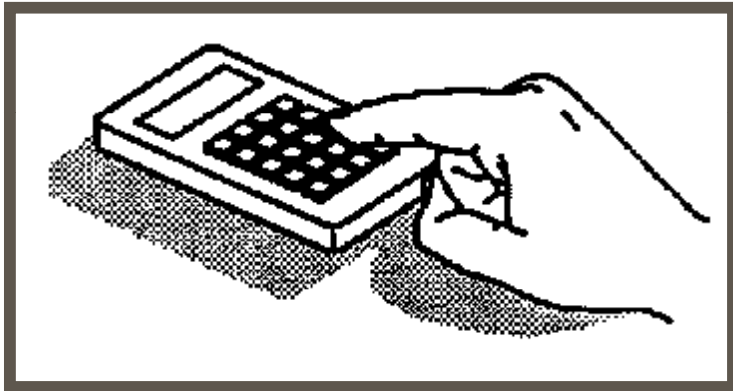
- **Distribution system for messages and files**
- **Manages alarm messages, Totalization files, Trend files and Point History files**
- **Concurrent updating of multiple locations for fault tolerance**

# Building Automation System



# Building Automation System

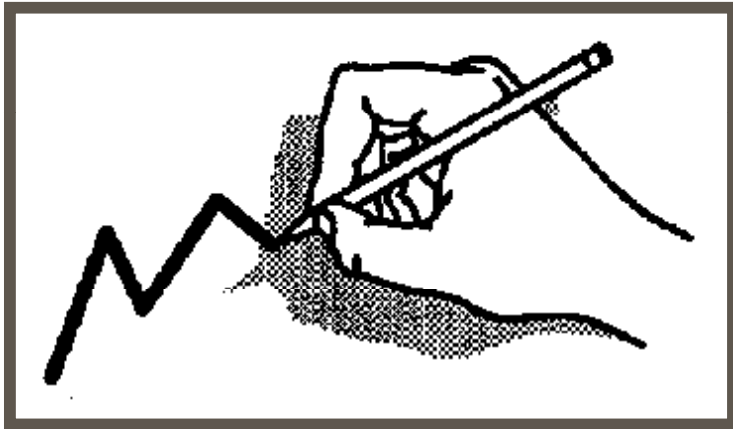
## *Totalization*



- **Maintains records of run-time**
- **Allows scheduling of preventive maintenance**
- **Built-in graphing functions**

# Building Automation System

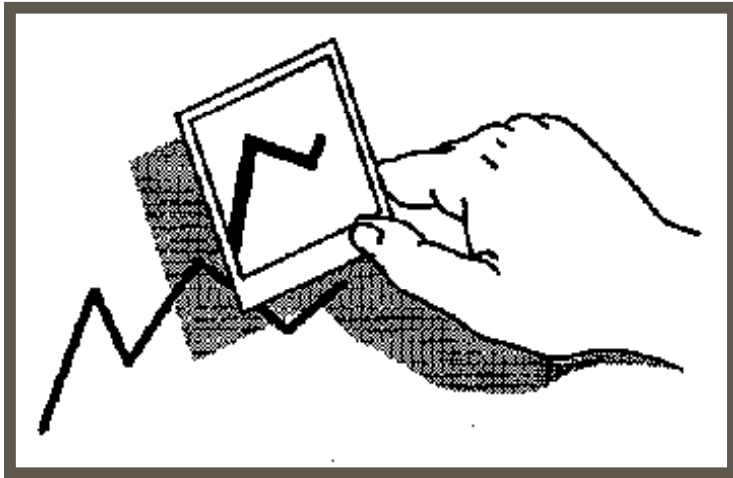
## *Trend*



- **Periodic sampling of selected points**
- **Used for trouble shooting**
- **Built-in graphing functions**

# Building Automation System

## *Point History*



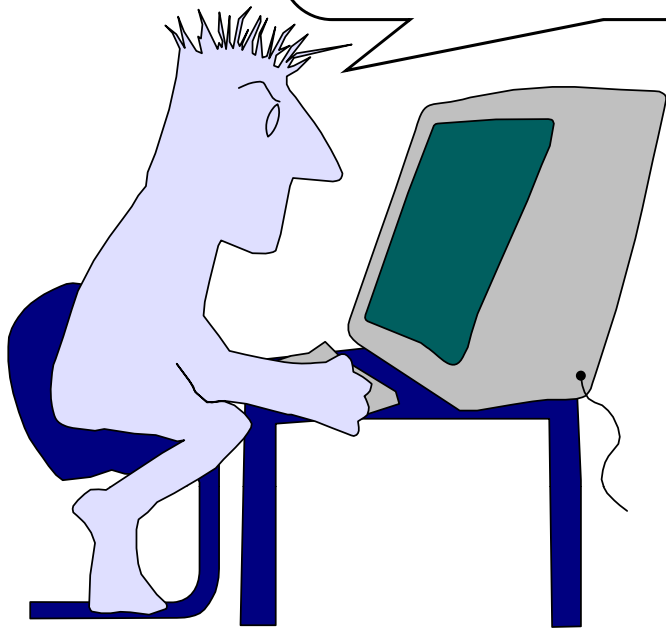
- **Continuous record of all points in BAS**
- **Allows proactive response to tenant complaints or alarms**
- **Built-in graphing functions**



# Building Automation System

## *Trend Only*

**I will start collecting data now and hope that the same problem happens again!**



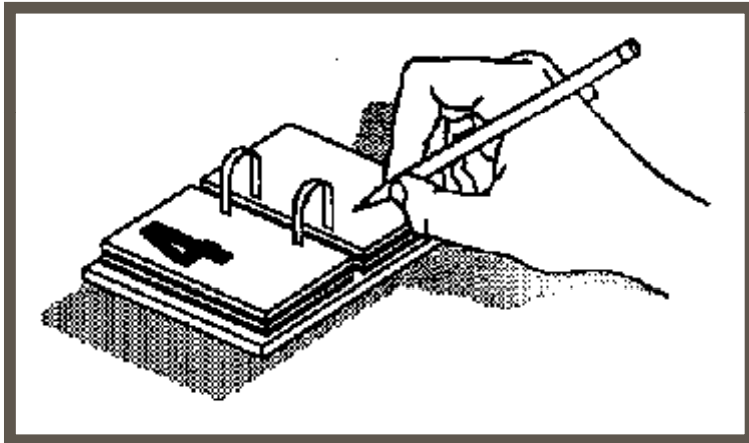
## *Point History*

**I always have the data required before I need it!**



# Building Automation System

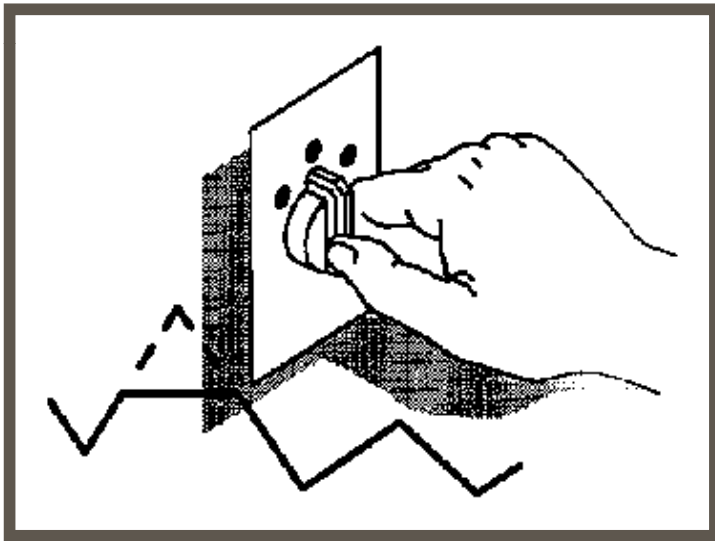
## *Scheduling*



- **Automatic execution of commands and summaries based on a time schedule**
- **One time schedules to accommodate special situations**
- **Major source of energy savings**

# Building Automation System

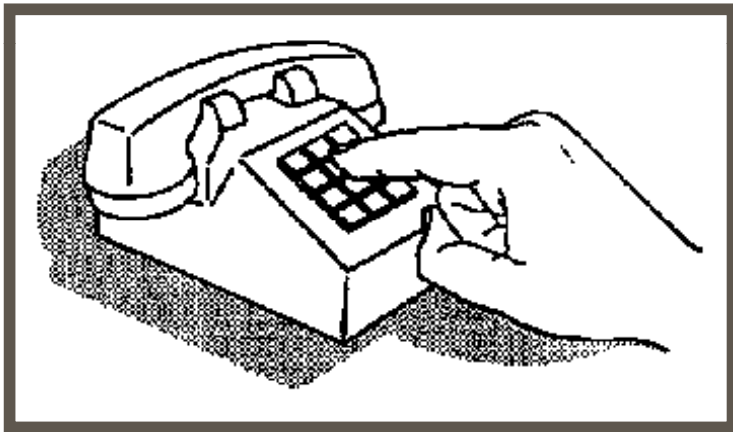
## *Demand Limiting / Load Rolling*



- **Advanced energy management algorithms**
- **Actions coordinated between features**
- **Prioritization of loads**
- **Utility profile to track electricity bills**

# Building Automation System

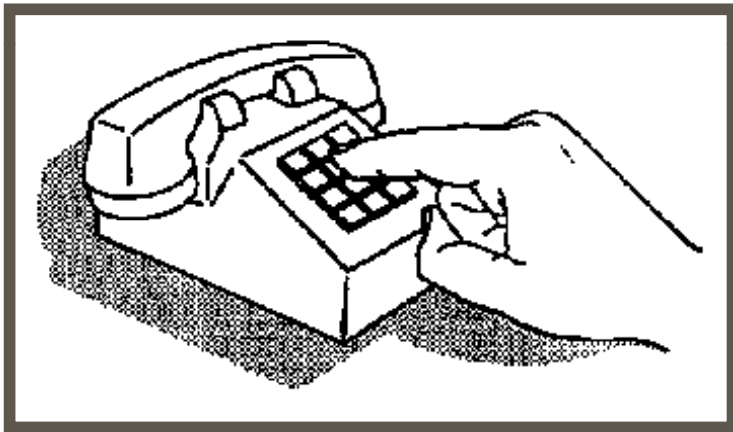
## *Telephone I/O Tenant Mode*



- **Tenants can use telephone to request overtime usage**
- **User-friendly voice prompts to simplify tenant training**
- **Transactions recorded for tenant billing**

# Building Automation System

## *Telephone I/O Operator Mode*



- **Automatic dial-out to operator in the event of an alarm to reduce manpower costs**
- **Supports direct voice or pager**
- **Operator can access system using any telephone**