Communication Protocols
通 訊 協 議
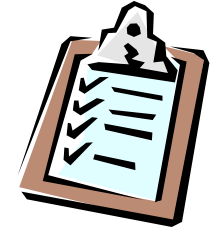
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Mar 2010

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- Basic Concepts

- Connectivity

- BACnet

- LonWorks

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Basic Concepts

- A "protocol" is a formal agreement (e.g. Kyoto Protocol and Montreal Protocol)

- A Communications Protocol is an agreement on how to exchange of information between intelligent devices such as PCs or controllers

- The OSI 7-layer model is commonly used to identify the structure of the agreement

  - P.S.: The OSI Model is not a protocol; compliance with it does not imply connectivity

Basic Concepts

- Data communication protocols
  - Sets of hardware and software rules, apply to:
    - Electrical signalling
    - Addressing
    - Network access (master/slave, peer-to-peer)
    - Error checking
    - Flow control
    - Message sequencing
    - Segmentation
    - Checkpointing
    - Presentation format (compression, encryption)
   - Message format

Basic Concepts

- The OSI 7-Layer model is ok for communications engineers, but a simpler, 3-layer model can be used to discuss BAS connectivity:

  - *Physical* : what media is used to connect the devices (i.e. twisted shielded pair, CAT-5 UTP structured cabling, coaxial cable, fiber optic cable)

  - *Delivery* : what standard is used to ensure messages are passed between devices (Ethernet, EIA232, EIA485, etc.)

  - *Information* : how is information represented (start/stop command, point value, etc.)

Examples of 3 layer model and an analogy to human communication

Physical	Paper	Paper	Coax	CAT-5 UTP
Delivery	Postal	Courier	Ethernet	LonTalk
Information	English	Chinese	BACnet	LonMark
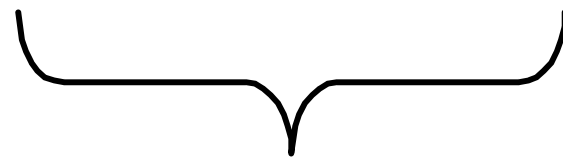
Human Communication
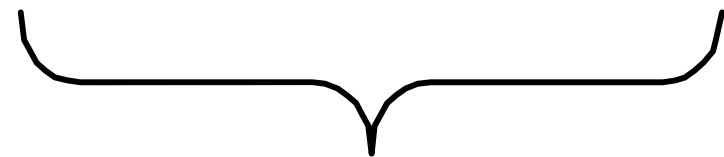
BAS Device Communication

For two devices to exchange information, they must both use the same physical, delivery and information layer.

Basic Concepts

- It may not be necessary to insist that devices agree on all three layers. For example:
    - For devices to use a common structured cabling system, they need only agree on the physical layer; this will allow common patch panels, common connectors and a common wiring management system to be used for all devices
    - For devices to "piggyback" onto an office automation (OA) LAN using Ethernet TCP/IP, they need only agree on the physical and delivery layers; the routers and bridges of the OA LAN need not understand the info contained in the messages to get the messages from one location to another

Basic Concepts

- An "Open Protocol" is available to anybody, including competitors (only a few BAS vendors have such)

- A "Restricted Protocol" has the circulation controlled by a vendor (most BAS vendors have this)

- A "Standard Protocol" must first be an "Open Protocol" and, in addition, it must be used by a number of vendors (there are many competing "Standard Protocols" used in the BAS industry)
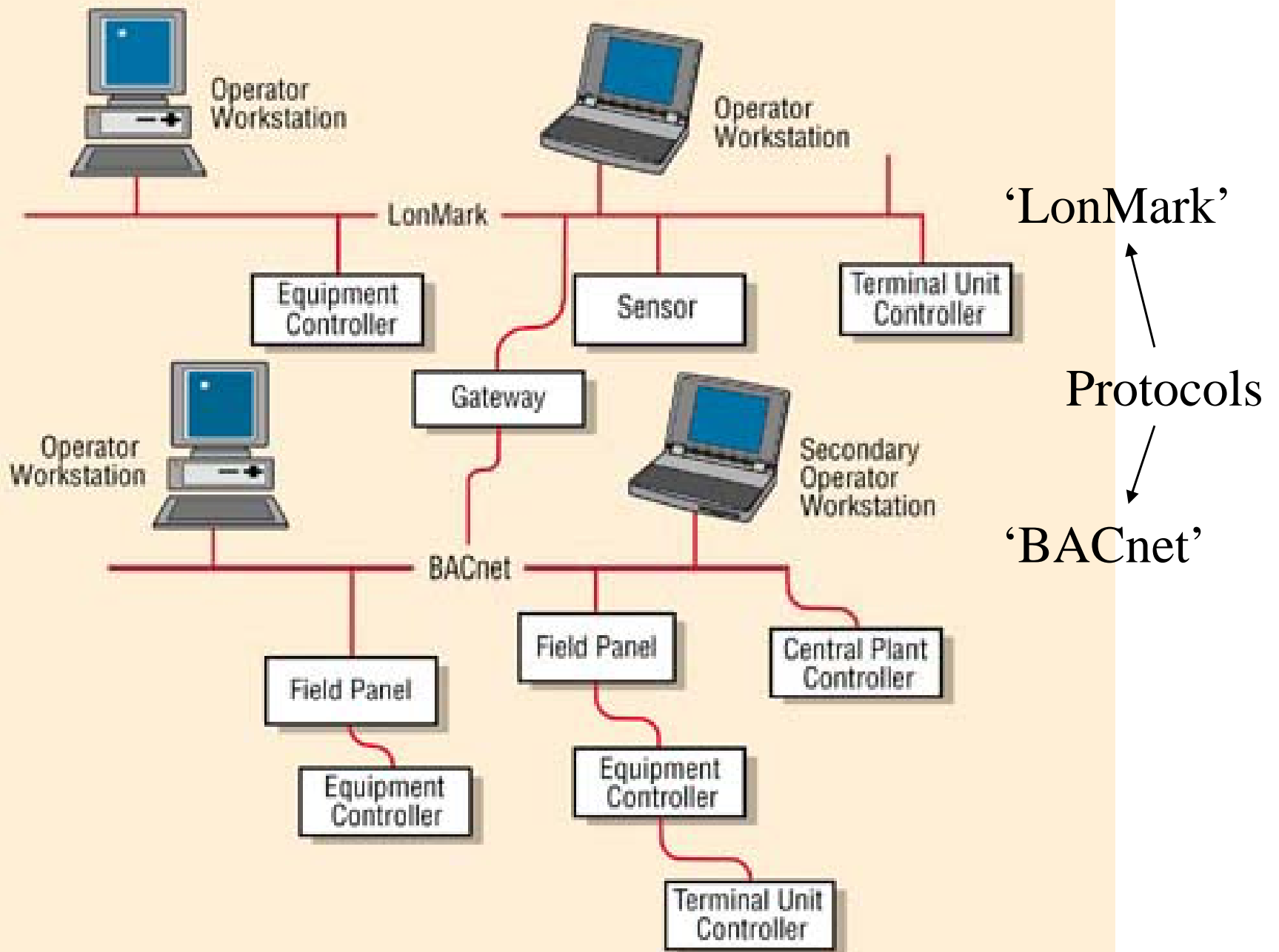
Basic Concepts

- Types of systems
  - Open systems
    - No secrecy; codes and configurations are disclosed
  - Closed systems
    - Protected by secrecy; are patented or copyrighted
  - Proprietary systems
    - Developed by a proprietor (holds legal right and exclusive title); the system may be open or closed
  - Non-proprietary systems
    - Do not have a proprietor; often developed by non-profit organisation and are open

Example of various types of HVAC DDC systems

Type	Open	Closed
Proprietary	LonWorks	Various DDC manufacturers
Non-proprietary	BACnet	None known

Modern building automation systems

Basic Concepts

- A BAS device can support only one protocol

- A BAS system can support a specific protocol in one of two ways:
  - *Native* : All devices in the system use this protocol. The protocol is used for all functions: (i.e. read, write, download, upload)
  - *Gateway* : Devices in the system do not use this protocol but a "protocol translator" is available. In this case, the specific protocol is typically only used for read and write but not upload or download

Connectivity

- BAS is a tool to assist in the management of the building. In today's environment, this means providing connectivity to a number of protocols.
  - 1. Existing vendor-specific protocols
  - 2. Competing "Standard" protocols
  - 3. Protocols from other industries
  - 4. Protocols from other BAS
- Which protocol is "native" to the BAS devices is irrelevant - what is important is the list of protocols to which the BAS system can connect
  - Being locked into any one protocol is not a good idea

Connectivity

- <u>Myths regarding Protocols</u>:
  - Compliance with the OSI 7-layer model implies connectivity
  - Use of a standard LAN such as Ethernet TCP/IP implies connectivity
  - Having an "Open Protocol" implies connectivity (Question: how many vendor's equipment can be connected using this "Open Protocol"; is it a "Standard Protocol"?)
  - Which protocol is native to the BAS device is important (Correction: what is important is the list of protocols to which the BAS can connect)

Layers of a BAS
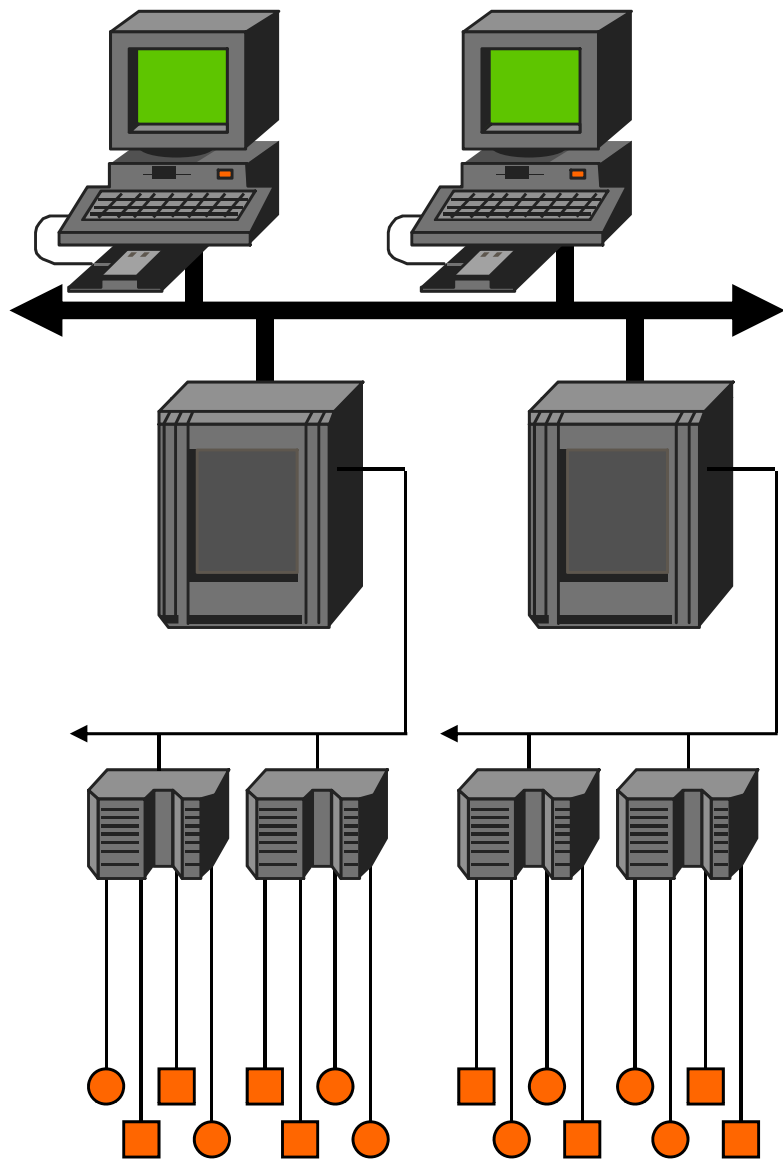
Management Layer

Operator Workstation
Graphical User Interface
Data Archiving

Automation Layer

System Controller
Historical Data Collection
Supervisory Control
BAS Features

Field Layer

DDC Controller
Connect to Sensors / Actuators
Equipment Level Interlocks
Control Loops

Layers defined by European
Standardization Committee

Connectivity

- Connectivity at each layer can be accomplished through one of two approaches:
  - "Native" standard
  - Gateway

- Each layer approaches connectivity differently because there are different objectives for connectivity at each layer and different technical / cost constraints at each layer

Connectivity

- [Field Layer](#)

  - Includes DDC Controllers and factory-mounted controllers

  - Responsible for connecting to sensors / actuators, equipment level interlocks and control loops

  - Very large quantity installed in a building, so "pennies count"; network cost must be low

  - Connectivity focus : integrating building equipment into BAS

Connectivity

- [Automation Layer](#)

  - Includes BAS System Controller

  - Responsible for historical data collection, supervisory control and BAS features

  - Small quantity installed in a building, so network cost is not critical

  - Connectivity focus : integrating other building systems into BAS

Connectivity

- <u>Management Layer</u>
  - Includes PC based Operator Workstations
  - Responsible for Graphical User Interface and Data Archiving
  - Small quantity installed in a building, so network cost is not critical
  - Connectivity focus : integrating other systems (i.e. office automation / factory automation) into BAS

BACnet

- BACnet = Data communication protocol for Building Automation and Control Networks system

  - A standard protocol designed by consensus to allow devices from different vendors to exchange information

Vendor 1 Controller

Vendor 2 Controller

Vendor 3 Island of Automation with BACnet ™ Gateway
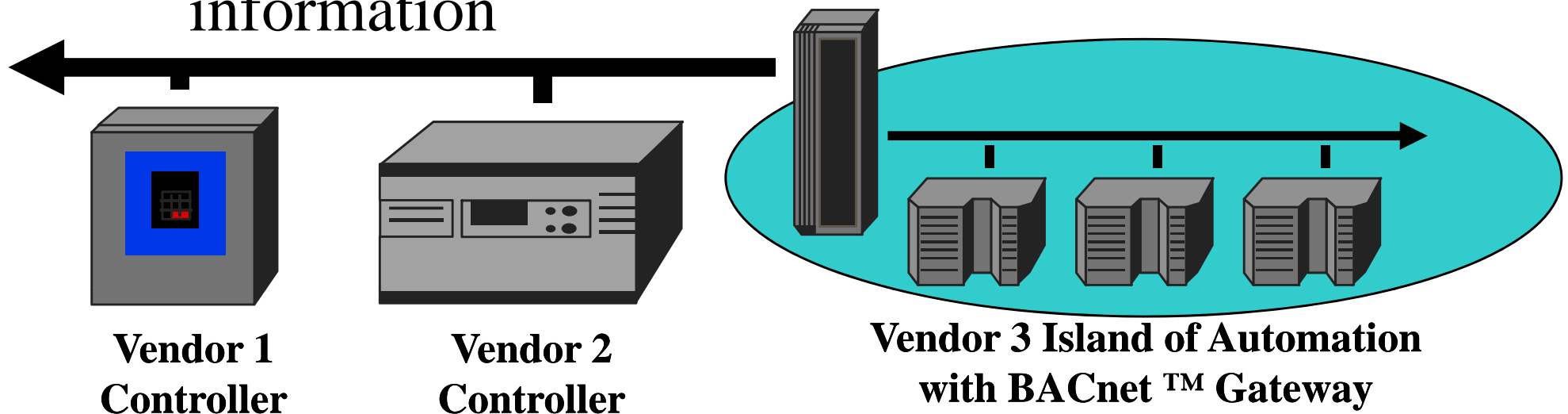
BACnet

- ## BACnet

  - Industry standard developed by ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) since 1987

    - Adopted in USA, Europe and many countries as the reference standard for BAS (e.g. ISO 16484-5)

  - BACnet applications: HVAC, fire, lighting, security, lifts, utility company interface

  - Use only layers 1, 2, 3 and 7 of the OSI model

BACnet infrastructure compared with the OSI model

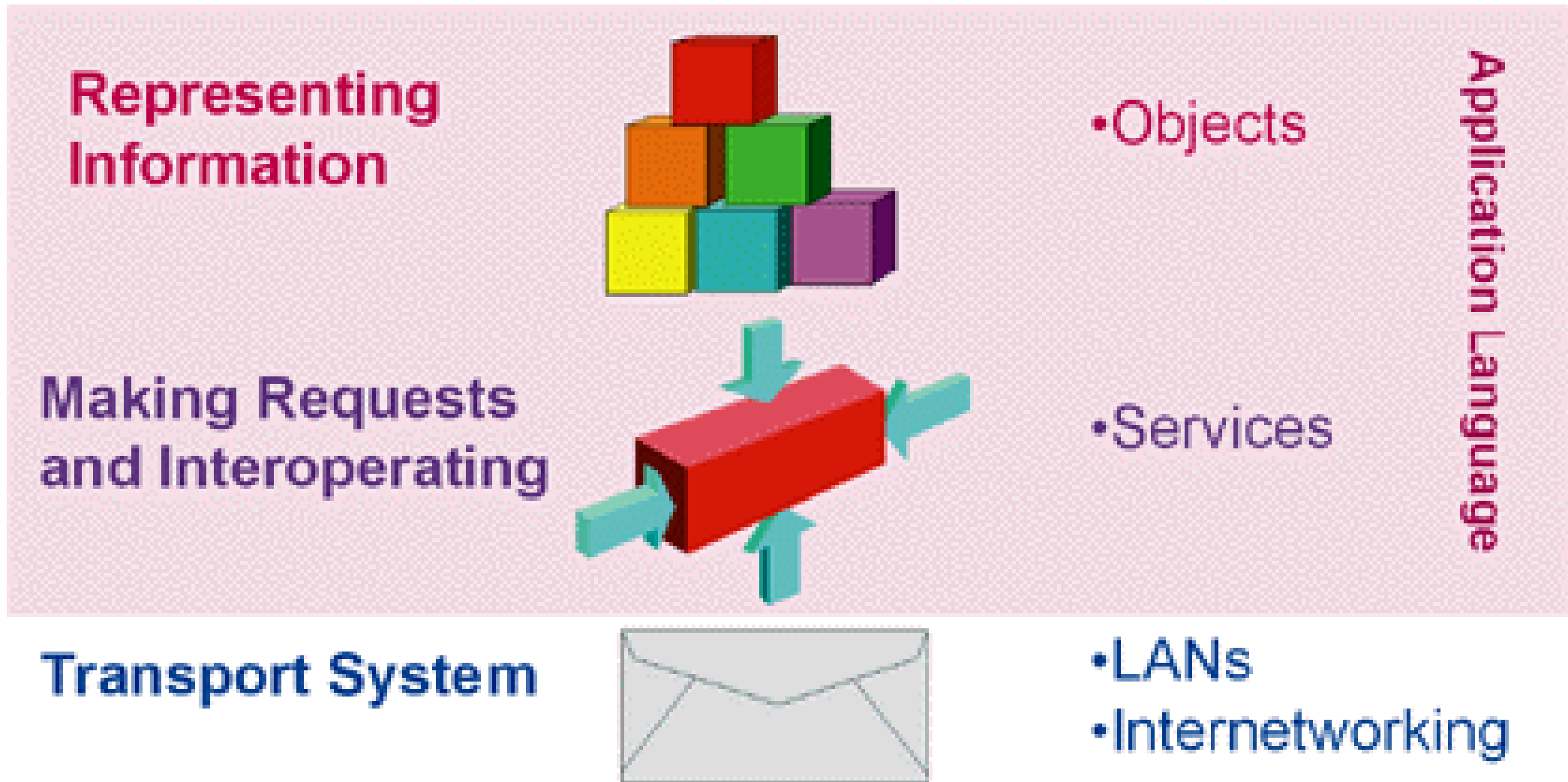| OSI Layers		BACnet Layers					
7	Application	BACnet Application					
3	Network	BACnet Network					
2	Data link	Ethernet	ARCNET	MS/TP	Point-to-point	IP	LonTalk
1	Physical	Ethernet	ARCNET	EIA-485	EIA-232	Internet	LonTalk

MS/TP = Master/Slave Token Passing; IP = Internet Protocol
* EIA-485 is most often used for application specific controllers (low cost)
* EIA-232 and point-to-point is typically used for dial-up access through a modem
LonTalk: commun. protocol for LonWorks network

How does BACnet work?

Representing Information

• Objects

Making Requests and Interoperating

• Services

Application Language

Transport System

• LANs
• Internetworking

BACnet

- ## BACnet Application Layer
  - ### Similar to OSI application layer
  - ### Consists of 18 standard types "objects", 35 "services", and 6 events "algorithms"
    - #### BACnet Objects
      - Used to identify and access info from various devices
      - Abstract data structures that represent various aspects of the software, hardware, or an operation, e.g. an analogue input, analogue value, binary output, calendar, and schedule
    - #### BACnet Services
      - Provide commands and additional services for objects

BACnet Standard Objects

Analog Input	Event Enrollment
Analog Output	File
Analog Value	Group
Binary Input	Loop
Binary Output	Multistate Input
Binary Value	Multistate Output
Calendar	Program
Command	Recipient Table
Device	Schedule

Plus vendor specific objects

Analog Input Properties

Object Identifier	Object Type	Present Value
Description	Device Type	Status Flags
State	Out of Service Flag	Update Interval
Units	Minimum Value	Maximum Value
Resolution	Vendor Specific Property #1	Vendor Specific Property #n

Each vendor is free to extend the standard set of properties with additional vendor specific properties

BACnet Standard Services

- Alarm and Event Services
- File Access Services
- Object Access Services
- Remote Device Management Services
- Virtual Terminal Services

Private transfer services are available to provide vendor specific capabilities

BACnet Protocol Data Units

- Confirmed Request
- Simple Acknowledge
- Segment Acknowledge
- Reject

- Unconfirmed Request
- Complex Acknowledge
- Error
- Abort
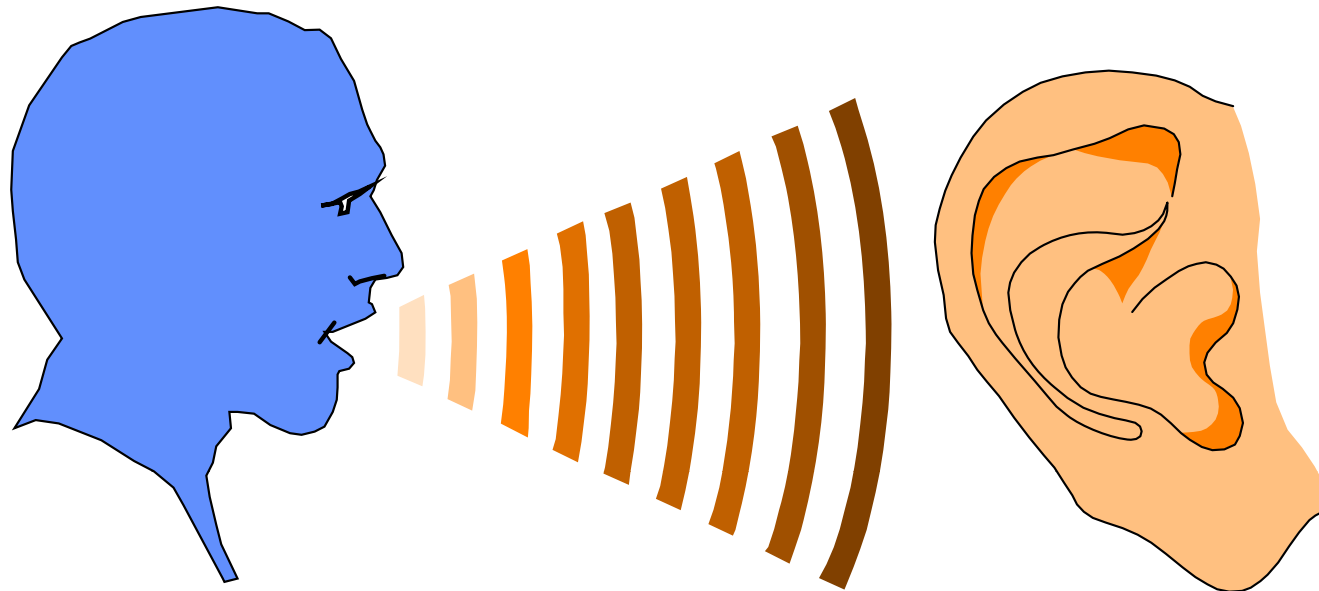
BACnet

- **BACnet Network Layer**
  - Similar to OSI network layer
  - Provide the means by which a message can be routed from one BAcnet network to another

- **BACnet Data Link Layer**
  - Similar to OSI local data link layer
  - Relates to the packaging and data transfer within one specific network
  - It allows 5 LAN technologies: Ethernet (ISO 8802-3), ARCNET (ANSI 878-1), master/slave token passing (ANSI/ASHRAE 135), point-to-point (ANSI/ASHRAE 135), LonTalk (Echelon)

BACnet

- <u>BACnet Physical Layer</u>
  - Similar to OSI physical layer
  - Refer to the physical media (wiring) in which data are transferred
  - Allows 6 LAN technologies:
    - Ethernet
    - ARCNET
    - EIA 485
    - EIA 232
    - Internet
    - LonTalk

BACnet

- Advantages of using Internet for BACnet systems
  - Allows 2 or more remote networks to communicate simultaneously & operate together
  - More powerful & faster remote access
  - Real-time integral operation
  - User friendly (everyone is familiar with Internet browser)
- Caution with Internet: security issues & hackers!

BACnet

- BACnet conformance classes
  - BACnet defines standard Protocol Implementation Conformance Statement (PICS) to allow proper conformance by various manufacturers
  - Has 6 levels of conformance
    - **Class 1 :** Receive "read value" message
    - **Class 2 :** Class 1 + receive "write value" message
    - **Class 3 :** Class 2 + receive "read/write attribute" message
    - **Class 4 :** Class 3 + send "read/write value" message + send "read/write attribute" message
    - **Class 5 :** Class 4 + receive "create/delete object" message
   - **Class 6 :** Class 5 + send "create/delete object" message

BACnet

- ## Native BACnet
  - A terminology adopted by BACnet manufacturers
  - Those DDC systems in which every component is BACnet compatible at the device level
  - 2 native BACnet devices can talk with minimal interface

- ## BACnet gateways
  - Gateways (= intelligent translator) as an interface between close proprietary systems and BACnet
  - Requires continuous maintenance; may create a bottleneck for info transfer

Interfacing old and new systems
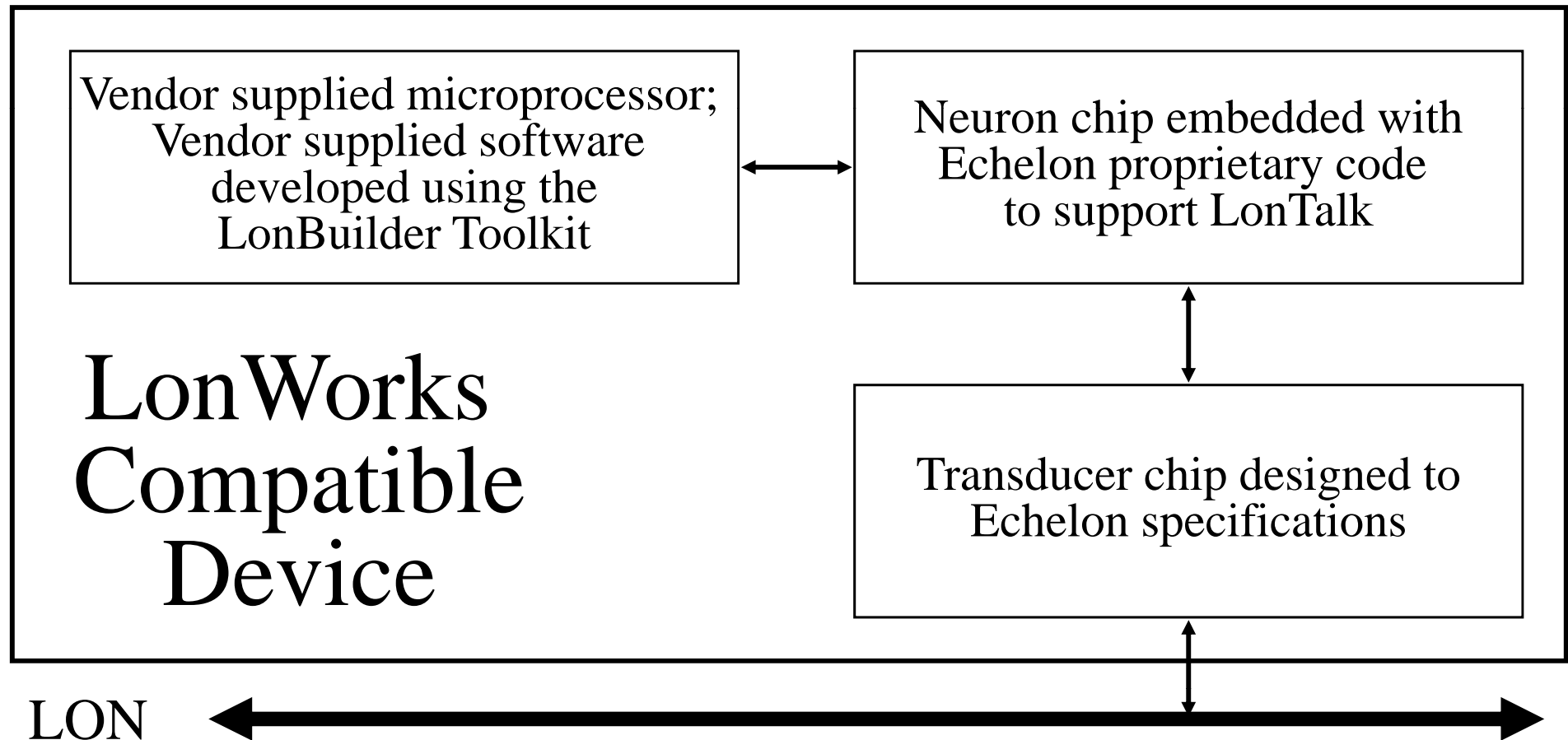

Old
System

New
System
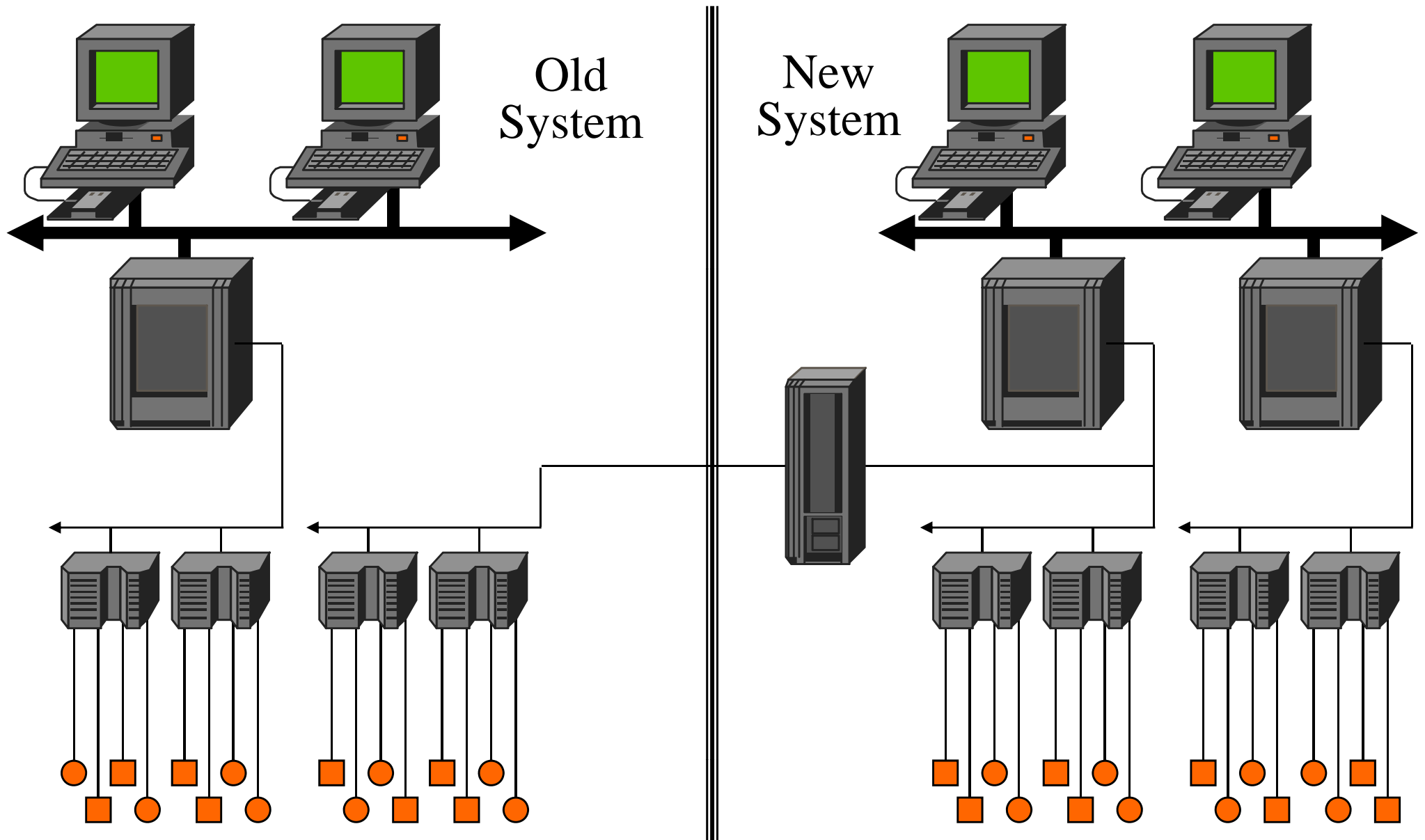
BACnet

- Further info about BACnet:
  - ASHRAE's BACnet committee (SSPC 135) http://www.bacnet.org
    - BACnet Tutorial Overview
    - BACnet/IP
    - BACnet: Answers to Frequently Asked Questions
    - Bibliography
  - BACnet International (BI) (formerly, BACnet Manufacturers Association)
    - http://www.bacnetassociation.org

LonWorks

- LonWorks is a family of hardware and software products developed by the Echelon Corporation (www.echelon.com)
  - LON = local operating network (designed to move short, event-driven, effective data)
  - LonTalk = open proprietary protocol for LonWorks; based on OSI 7-layer model
    - Provide the set of rules and methods for managing and exchanging messages between nodes and devices

LonWorks

LonWorks compatible devices must use
transducer and Neuron chip from Echelon.

LonWorks Compatible Device

Vendor supplied microprocessor; Vendor supplied software developed using the LonBuilder Toolkit	Neuron chip embedded with Echelon proprietary code to support LonTalk
	Transducer chip designed to Echelon specifications

LON

LonWorks

- LonWorks: Physical Layer
  - The following options are supported:
    - Twisted pair
      - 1,250K baud (Transformer coupled Twisted Pair / Bus)
      - 78K baud (Twisted Pair/Free Topology)
        - Can supply up to 36.5 watts of DC power to devices
        - Supports bus / star / loop / combination topologies
      - 39K baud using standard EIA485 signaling
    - Power line carrier (10K, 5K or 2K baud)
    - Radio frequency (4.8K baud)

LonWorks

- **LonTalk: Delivery Layer**
  - Echelon proprietary; embedded in "Neuron" chip
  - Peer-to-Peer communications
  - Similar to Ethernet, except:
    - Lower cost implementation
    - Each device monitors network traffic level for advanced collision avoidance
    - Devices can be prioritized
    - Designed for real-time control networks rather than batch-oriented OA networks
    - Optimized for small messages (<66 bytes)

LonWorks

- ## LonTalk protocol
  - Designed specifically for control systems
    - Small packets (temp., pressure, status, etc, at about 12 bytes/packet) but can require hundreds or thousands of nodes and have the ability to send their packets within a very short time
    - [c.f.: data networks – large data packets (kilobyte or megabyte packets) with a relatively small amount of simultaneous users]
  - Date types, profiles, etc. reviewed by the LonMark Interoperability Association (ensure they are interoperable)
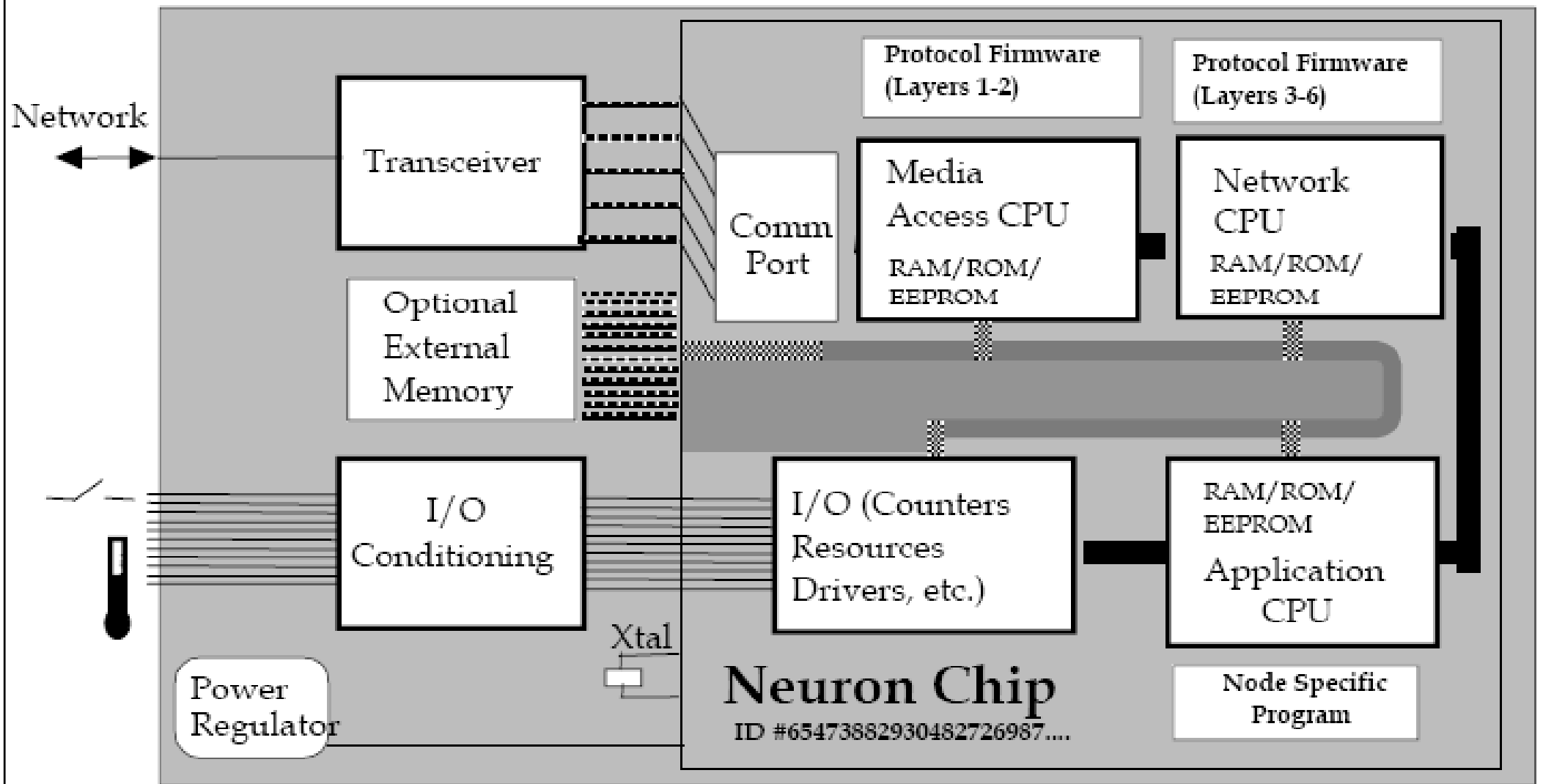
LonWorks

- [Neuron chip](#)   神經元芯片

  - It is a microprocessor typically embedded in LonWorks products (to simplify the process for standardisation)

    - A complete system programmed on a chip; contains Read-Only Memory (ROM), Random Access Memory (RAM), and the input/output interface ports and communications protocol

    - "Neuron" = nerve cell body and all its process

  - Includes 3 microprocessors or CPU:

    - **CPU-1**: media access control (MAC) processor (layers 1 & 2 of OSI 7-layer model)

    - **CPU-2**: network processor (layers 3 to 6 of OSI 7-layer model)

    - **CPU-3**: application processor (run codes written by the user and manufacturer)

LonWorks device components

Network

Transceiver

Optional External Memory

I/O Conditioning

Power Regulator

Xtal

Comm Port

Protocol Firmware (Layers 1-2)

Media Access CPU

RAM/ROM/ EEPROM

Protocol Firmware (Layers 3-6)

Network CPU

RAM/ROM/ EEPROM

I/O (Counters Resources Drivers, etc.)

RAM/ROM/ EEPROM

Application CPU

Neuron Chip

ID #6547388293048272698?....

Node Specific Program

LonWorks

- **LonWorks SNVTs**
  - SNVT = Standard Network Variable Type
  - LonWorks controllers uses it to define data objects
  - SNVT allows for implementation of multiple applications for multiple manufacturers and make it easier for interpretation
- **LonWorks SCPTs**
  - SCPT = Standard Configuration Parameter Type
  - Provide a standard for documenting network message formats
  - SCPTs are used to download configuration data e.g. set points, offsets, gains, etc. to the devices by the network management tools

LonWorks

- LonWorks Transceivers
  - Transceiver = transmitter + receiver
  - Means of communication between the LonWorks network and the Neuron Chip
  - To interoperate properly, products must have compatible transceivers, otherwise, a router will be required
- LonWorks Routers
  - Intelligent hardware that filter the passing of messages between two network segments
  - Used to extend the length of a network or the number of nodes, and/or to change the media type
  - Can be configured in 3 ways: 1) a learning router, 2) a configured router, 3) a repeater

LonWorks

- What is [LonMark](#)?

  - A brand name and an association (formed in 1994), to promote and support those manufacturers that produce "interoperable" LonWorks products

  - Provide device-level assurance of interoperability through certification (LonMark logo)

    - Not all LonWorks products are LonMark certified
    - Different levels of how LonTalk is implemented

  - LonMark = Information Layer

LonWorks

- Further info about LonWorks:
  - Echelon LonWorks system
    http://www.echelon.com
    - Online LonWorks Demonstrations
    - Introduction to the LonWorks System (PDF)
  - LonMark Interoperability Association
    http://www.lonmark.org
    - LonMark Design Guidelines
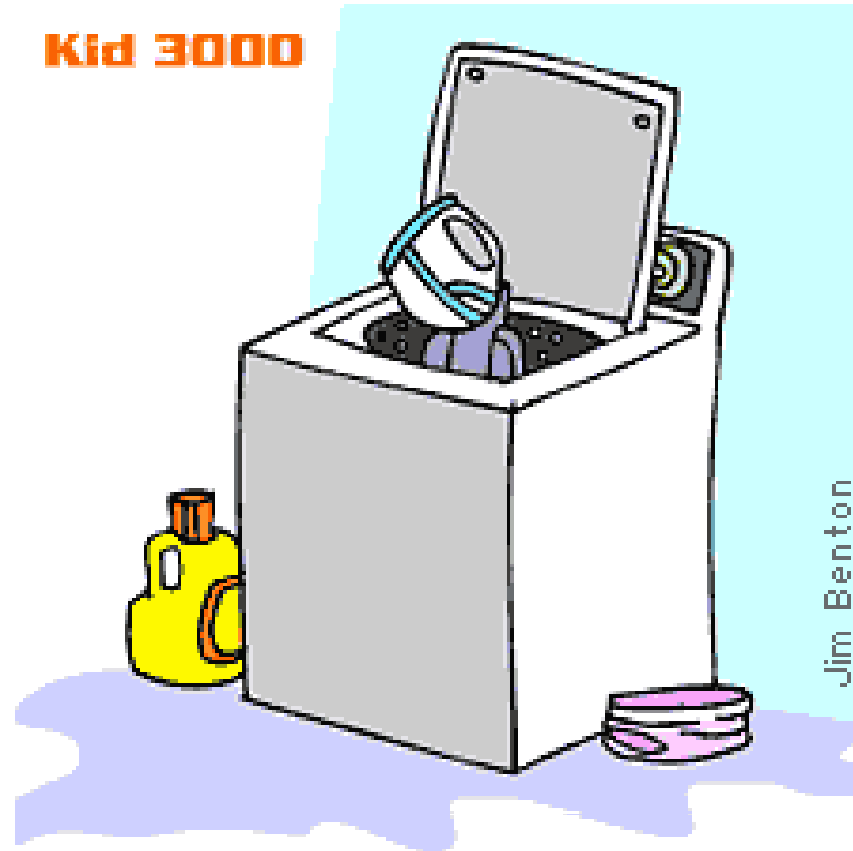   - LonMark Technical Corner

The Future of BEMCS

- What we have learned so far:
  - Hardware Components
  - System Architecture
  - Networking
  - Communication Protocols
- Hot topics/issues:
  - Interoperability
  - Open system interconnectivity (OSI)
  - Integrated networks

Make A Wish List

Kid 3000

Jim Benton

Futuristic underwear, programmed
with artificial intelligence, will wash
themselves as necessary.

Homework

- What would you like to have in the future?
  - Each student make a [WISH](#)
  - Send your wish description to me by email (cmhui@hku.hk)
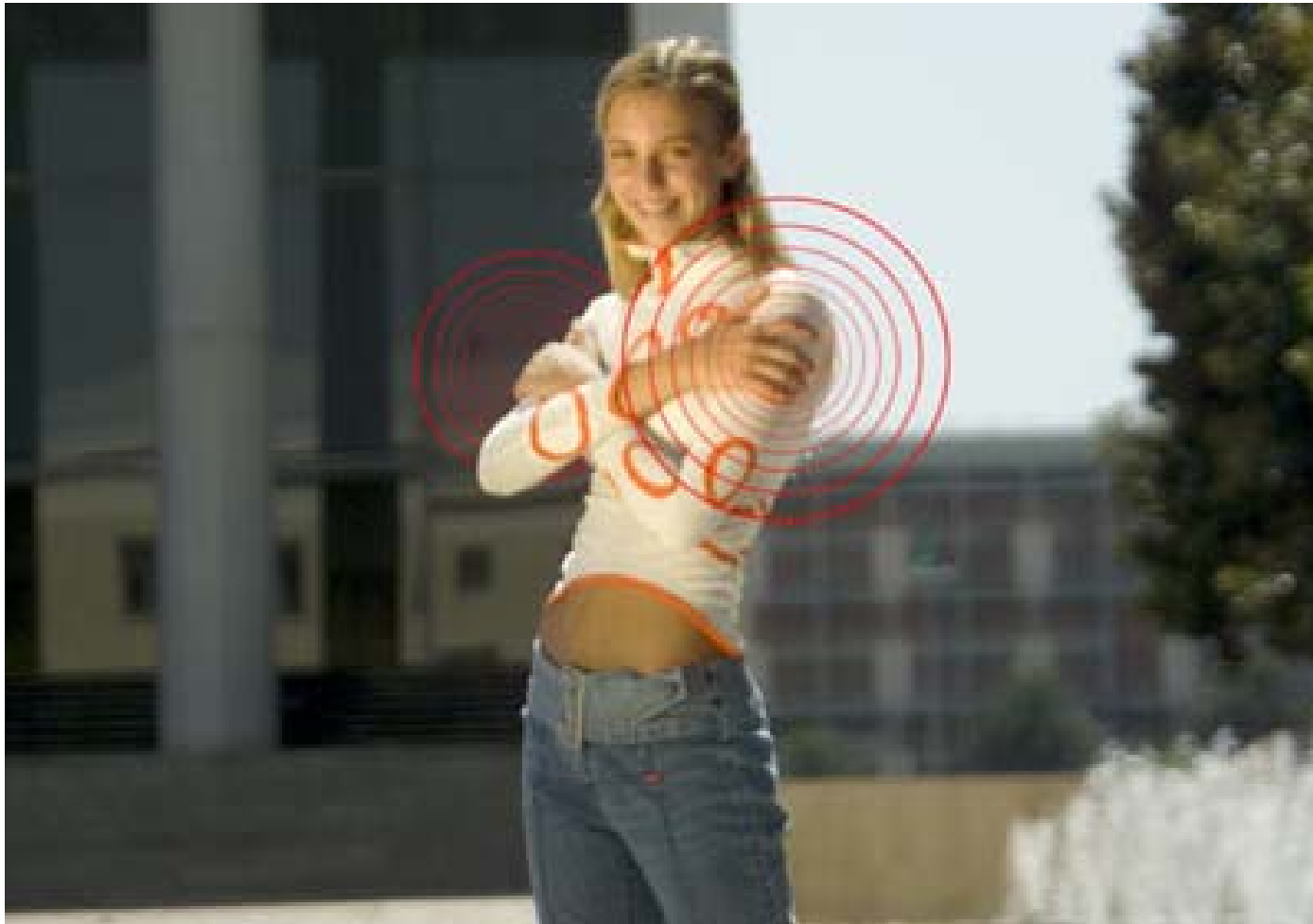- Wish List on BEMCS by Our Students
  - http://www.hku.hk/bse/mech3023/wishlist.htm

Make A Wish List

Kid 3000

Jim Benton

By the year 3000, you'll always have a cool place to sleep on hot summer nights.

Make A Wish List

Make A Wish List

Talking T-shirt (www.forbes.com)

Make A Wish List

Cooling jacket (www.forbes.com)

IMAGINATION
is more
important
than
knowledge.
–Albert
Einstein