ARCnet

- Understand Standard ARCnet
- Understand ARCnet ANSI/ATA 878.1 Standard
- Study ARCnet as a control network

Reference:

•http://www.arcnet.com/

•http://www.ccontrols.com/pdf/Tutorial.pdf

•http://www.delmar.edu/Courses/ITNW2313/arcnet.htm

•Networking and Integration of Facilities Automation Systems, Chapter 4

Standard ARCnet

- operate at 2.5 Mbps throughput
- connected using RG-62 A/U coax cable with 93Ω terminators (typical) or unshielded twisted pair (UTP) wiring
- support up to 255 node numbers on a single network (systems of this size are not practical)
- use a token-bus packet passing scheme
- The maximum distance an ARCnet signal can travel between the two nodes farthest away from each other is 20,000 feet
- the maximum time for the ARCnet signal to travel is 31μs

•Attached Resource Computer NETwork (ARCnet) was founded by the Datapoint Corporation in late 1970s

•ARCnet was one of the topologies used early on networking and is rarely used as the topology of choice in current LAN environments. ARCnet, however, still is a solid, functional and cost-effective means of networking.

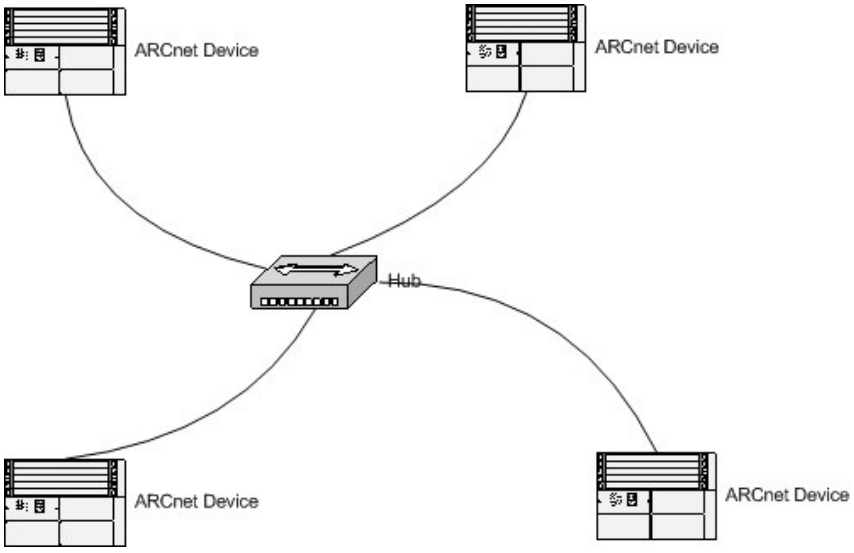
•Each device on an ARCnet network is assigned a *node number*. This number must be unique on each network and in the range of 1 to 255.

•ARCnet manages network access with a *token passing bus* mechanism. The token (permission to speak on the network) is passed from the lowest number node to higher number nodes in ascending order. Lower numbered addresses get the token before the higher numbered addresses.

•Network traffic is made more efficient by assigning sequential numbers to nodes using the same order in which they are cabled. Choosing random numbers can create a situation in which a node numbered 23 can be a whole building away from the next number, 46, but in the same room as numbers 112 and 142. The token has to travel in a haphazard manner that is less effective than if you numbered the three workstations in the same office sequentially, 46, 47, and 48, and the workstation in the other building 112. With this configuration, the packet stays within the office before venturing on to other stations.

•A maximum time limit of 31 microseconds is allotted for an ARCnet signal. This is also called a *time-out setting*. Signals on an ARCnet can travel up to 20,000 feet during the *31 microsecond* default time-out period. You can sometimes extend the range of an ARCnet by increasing the time out value. However, 20,000 feet is the distance at which ARCnet signals begin to seriously degrade. Extending the network beyond that distance can result in unreliable or failed communication. Therefore, the time-out parameter and cabling distance recommendations should be increased only with great caution.

Standard ARCnet Connection

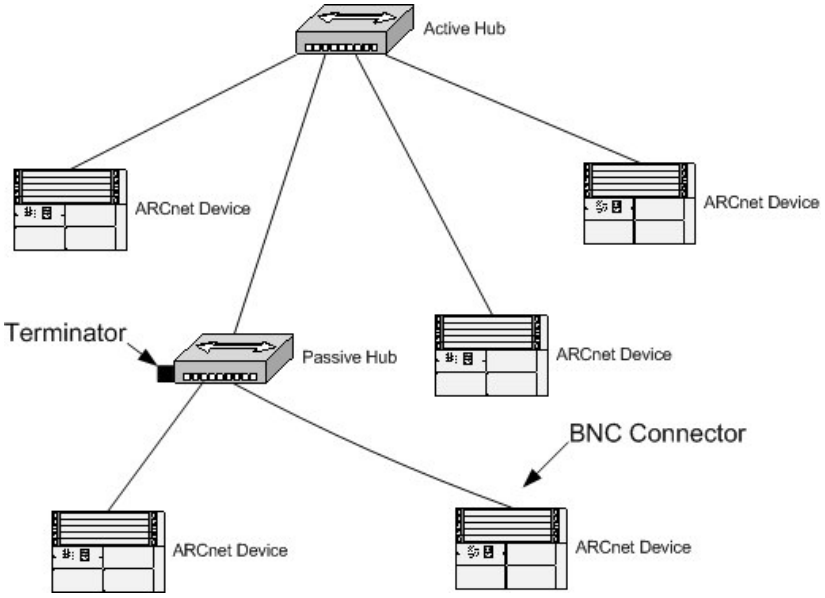


Control Network: ARCnet

Page 3

- An ARCnet network is used primarily with either coax or twisted pair cable. Most older ARCnet installations are coax and use RG-62 A/U type cable terminated with 93 Ohm terminators. Twisted pair (UTP) installations are newer and use stranded 24 or 26 gauge wire, or solid core 22, 24, or 26 gauge type cable terminated with 100 Ohm terminators. Many ARCnet networks use a mix of both coax and UTP cabling. UTP cable is simple to install and provides a reliable connection to the devices, whereas coax provides a means to span longer distances.
- Typical ARCnet installations are wired as a star. ARCnet can run off a linear bus topology using coax or twisted pair as long as the cards specifically support BUS. The most popular star-wired installations of ARCnet run off two types of hubs:
    1. *Passive hubs* cannot amplify signals. Each hub has four connectors. Because of the characteristics of passive hubs, unused ports must be equipped with a terminator, a connector containing a resistor that matches the ARCnet cabling characteristics. A port on a passive hub can only connect to an active device (an active hub or an ARCnet device). Passive hubs can never be connected to passive hubs.
    2. *Active hubs* have active electronics that amplify signals and split them to multiple ports. The number of ports on an active hub varies with the manufacturer, but eight is typical. A port on an active hub can be connected to a port on another active device (such as another active hub or an ARCnet device) or to a passive hub.
- One of the greatest flexibilities of ARCnet is that you can integrate connections from active hubs to a linear bus connection as long as you terminate at the last connection point.

ARCnet Network with Coax



Control Network: ARCnet

Page 4

- In cabling ARCnet networks with coax cable, you must follow several rules:
    1. Never connect a passive hub to another passive hub directly.
    2. Passive hubs should never be used to connect two active hubs.
    3. Passive hubs are only used to connect an active hub and a node.
    4. Unused connectors on active hubs do not need to be terminated.
    5. Unused connectors on passive hubs must be terminated using a 93 Ohm terminator.
- The figure above shows an ARCnet configuration using active and passive hubs. Active hubs are required to extend the network for long distances and to configure networks that have more than four nodes. Passive hubs are used as an economical means of splitting a port on an active hub to support three devices.

ARCnet Cable Distance

Maximum ARCnet Cable Distances		
Max Distance	From	To
2000 ft	Network node	Active hub
2000 ft	Active hub	Active hub
100 ft	Active hub	Passive hub
Not supported	Passive hub	Passive hub
100 ft	Network node	Passive hub
2000 ft	Network node	Network node
20000 ft	Farthest node	Farthest node

Trouble Shooting

- Duplicate addresses
- Terminators
- Failure of network interface
- Failure of active hubs (or a port on that hub)
- Exceed specifications of cable lengths
- Bad connectors

•*Duplicate addresses*: No more than one node can have a given node address on the same network. If two or more nodes share an address, one of the two workstations will either lose its network connection or will not be able to find a network.

•*Missing terminators*: Missing terminators may not present visible problems on a small network. Missing terminators cause data retransmits on smaller systems, eventually appearing as transmit time out errors or network errors.

•*Using a terminator with an incorrect rating*: Coax uses 93 Ohm; UTP must use 100 Ohm terminators. A terminator's value in ohms depends on the impedance of the cable. The cable's impedance and the terminator's value should always match.

•*Failed network interface*

•*Failed active hubs* (or a port on that hub)

•*Cable lengths that exceed specifications*: Twisted pair, cabled in a bus rather than a star, cannot have more than ten devices per segment. This number varies with different manufacturers. ARCnet UTP installed in a bus configuration is generally used only in very small networks of six nodes or less. This configuration has the major drawback of halting the network if a single cable is disconnected. In an ARCnet bus configuration, the network must be brought down to make any changes or service to the ARCnet interface cards.

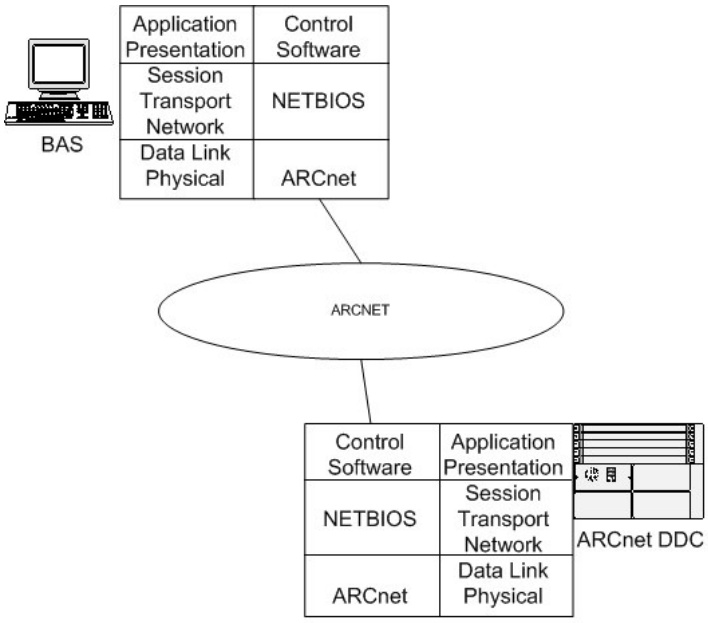
•*Coax connector not built and/or crimped correctly*: Twist-on connectors are responsible for more intermittent errors on a network than most other failures because of their design.

ARCnet Standards

- ANSI/ATA 878.1
  Local Area Network: Token Bus (2.5Mbps)
- ATA 878.2 (draft)
  ARCnet Packet Fragmentation Standard
- ATA 878.3 (draft)
  Encapsulation Protocol Standard

- ARCnet was originally developed for office automation network in the late 1970s.
- Its use as an office automation has diminished; however, ARCnet continues to find success in the *field level* automation industry because its robustness, deterministic performance and long cable distances.
- ARCnet ANSI/ATA 878.1 standard was developed by the ARCnet Trade Association (ATA) and approved by the American National Standards Institute (ANSI) in 1992.
- ARCnet Standard:
  1. *ANSI/ATA 878.1* - This standard defines the frame format, medium access, services, active hub operation, and the physical layer functions and connectors for a token bus LAN operating at 2.5 Mbps.
  2. *ANSI/ATA 878.1-1999* – Broaden the 878.1 standard to include alternate physical layers such as fiber optics and EIA-485 communications as well as alternate data rates.
  3. *ATA 878.2 (Draft)* - This standard defines the method and the frame formats by which a block of data can be transferred utilizing ARCNET independent of the number of octets in the block of data. The standard defines a protocol by which data can be fragmented into one or more ARCNET frames and re-assembled at the receiving station.
  4. *ATA 878.3 (Draft)* - This protocol encapsulation standard defines a method to embed or encapsulate an existing protocol onto an ATA 878 (ARCNET) network. This standard allows devices using RS-232, RS-422/485 point to point standards to migrate upward to a high-speed network with multi-master capabilities.
- Over the years, ARCnet has developed a large customer base for smaller LAN real-time automation systems, including building automation and industrial controls systems. Its success can be attributed to its high speed deterministic nature and its high reliability

ARCnet layers



Control Network: ARCnet

Page 8

- ARCnet is a data-link layer technology with no defined application layer (i.e., defines two lower layers of the OSI model: data link and physical layers)
- The token-passing MAC defines five transmission types:
    1. Invitation to transmit (ITT): the token
    2. Free buffer enquiry (FBE): a query from the transmitting node to destination node to check buffer availability
    3. Data packet (PAC): the data transmitted between nodes (8 to 516 characters)
    4. Positive acknowledgement (ACK): acknowledgement of recipient
    5. Negative acknowledgement (NAK): of FBE and PAC from the destination node

ANSI/ATA 878.1 Physical Layer

Permissible Cable Lengths and Nodes Per Segment

Transceiver Description	Cable	Connectors	Cable Length		Max Nodes	Notes
			Min	Max	Bus Segment	
coaxial star	RG-62/u	BNC	0	2000ft/610m	N/A	5.5 dB/1000ft max
coaxial star	RG-59/u	BNC	0	1500ft/457m	N/A	7.0 dB/1000ft max
coaxial bus	RG-62/u	BNC	6ft/2m[1]	1000ft/305m	8	5.5 dB/1000ft max
duplex fiber optic (850 nm)	50/125	SMA or ST	0	3000ft/915m	N/A	4.3 dB/km max
duplex fiber optic (850 nm)	62.5/125	SMA or ST	0	6000ft/1825m	N/A	4.3 dB/km max
duplex fiber optic (850 nm)	100/140	SMA or ST	0[2]	9000ft/2740m	N/A	4.0 dB/km max
duplex fiber optic (1300 nm)	single mode	ST	0	46000ft/14000m	N/A	0.5 dB/km max
duplex fiber optic (1300 nm)	50/125	ST	0[2]	32800ft/10000m	N/A	1.5 dB/km max
duplex fiber optic (1300 nm)	62.5/125	ST	0[2]	35000ft/10670m	N/A	1.5 dB/km max
twisted-pair star	IBM type 3	RJ-11	0	330ft/100m	N/A	uses internal BALUNs
twisted-pair bus	IBM type 3	RJ-11, screw	6ft/2m[1]	400ft/122m	8	
DC coupled EIA-485	IBM type 3	RJ-11, screw	0	900ft/274m	17	DC coupled
AC coupled EIA-485	IBM type 3	RJ-11, screw	0	700ft/213m	13	transformer isolated

[1] This represents the minimum distance between any two nodes or between a node and a hub.
[2] May require a jumper change to achieve this distance.

- ARCnet supports bus, star and tree (distributed star) topologies
- Media support includes coax, TP, fibre

ANSI/ATA 878.1 Data Link Layer

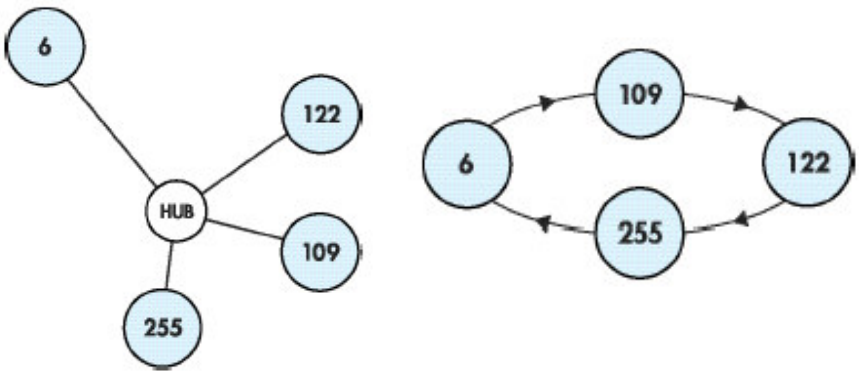
- ITT – Invitation to Transmit
  - <SD><EOT><NID>NID>
- FBE – Free Buffer Enquiry
  - <SD><ENQ><DID><DID>
- ACK – Acknowledgement
  - <SD><ACK>
- NAK – Negative Acknowledgement
  - <SD><NAK>
- PAC – Packet
  - <SD><SOH><SID><DID><DID><CP><SC><…DATA…><FCS>

ARCNET ANSI/ATA 878.1						
6 bits	11 bits	11 bits	22 bits	8 or 16 bits	11 to 5588 bits (1 to 508 octets)	16 bits
Preamble	SOH	Source Address	Destination Address	Length	SC/Data	Frame Check Sequence

- Basic Symbol Units are the elements used to construct basic frames and reconfiguration bursts:
  1. <SD>Starting Delimiter (all ARCnet frames begin with this symbol unit)
     1 1 1 1 1 1 (6 symbols)
  2. <RSU>Reconfiguration Symbol Unit
     1 1 1 1 1 1 1 1 0 (9 symbols)
  3. <ISU>Information Symbol Unit (each information unit contains 8 bits of data and 3-bit preamble)
     1 1 0 d0 d1 d2 d3 d4 d5 d6 d7 (11 symbols)
- The data in <ISU> can be:
  1. <SOU>Start of Header 0x01 (used to identify a packet)
  2. <ENQ>Enquiry 0x85 (used to identify a request for a free buffer)
  3. <ACK>Acknowledgement 0x86 (used to identify acceptance)
  4. <NAK>Negative Acknowledgement 0x15 (used to identify non-acceptance)
  5. <EOT>End of Transmission 0x04 (used to identify a token pass to the logical neighbor)
  6. <NID>Next Node Identification 0x01 to 0xff (used to identify the next node in the token loop)
  7. <SID>Source Node Identification 0x01 to 0xff (used to identify the source node of a packet transmission)
  8. <DID>Destination Node Identification 0x000 to 0xff (used to identify the destination node of a transmission request or a packet transmission)
  9. <CP>Continuation Pointer 0x03 to 0xff (used to identify the length of packet.)
     In short packet mode (0 to 252 bytes), the CP requires only one <ISU>.
     In long packet mode (256 to 507 bytes), the CP requires two <ISU>.)
  10. <SC>System Code 0x00 to 0xff (used to identify a high level protocol, the ATA has a list of SC assignments)
  11. <…DATA…>Data (the user data)
      Packet with size of 253, 254 or 255 ISUs are called exception packets and must be padded with null data and sent as a long packet
  12. <FCS>Frame Check Sequence 0x00 to 0xffff (cyclic redundancy check CRC-16)

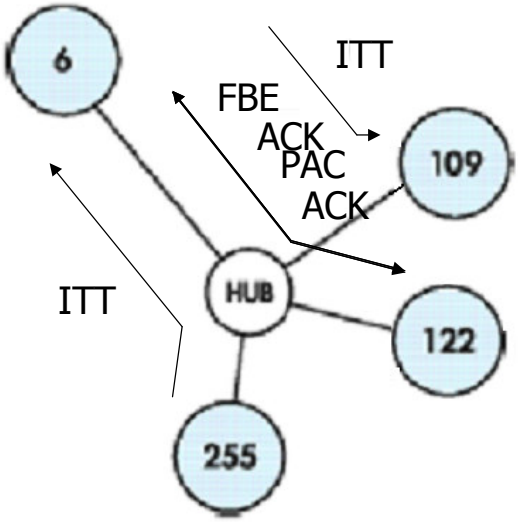
Logical Ring

- Physical Connection Logical Ring



- A token is passed in an orderly fashion among all the *active* nodes in the network
- For example:
    1. A network consisting of four active nodes addressed 6, 109, 122 and 255, connected in a star topology as shown above
    2. Once the network is configured, the token is passed from one node to the node with the next highest node address even though another node is physically closer
    3. All nodes have a logical neighbor and will continue to pass the token to their neighbor in a logical ring fashion regardless of the physical topology of the network, e.g., 6 – 109 – 122 – 255 – 6 - …

Directed Messages

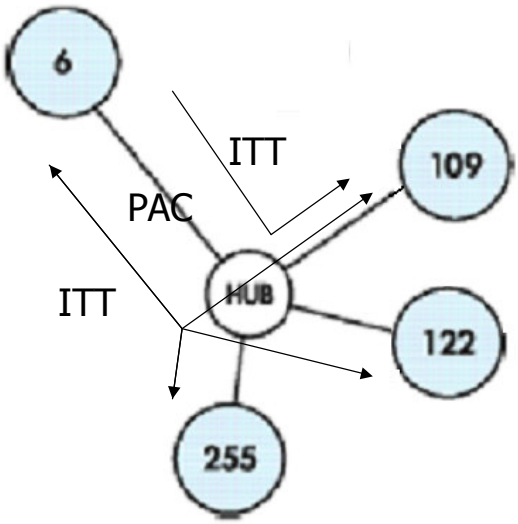


Control Network: ARCnet

Page 12

- Directed Messages:
    1. Source node, which has grabbed the token to talk, inquires if the destination node is in a position to accept a transmission by sending out a FBE.
    2. The destination node responds by returning an ACK meaning that a buffer is available or by returning a NAK meaning that no buffer is available.
    3. Upon an ACK, the source node sends out a PAC with either 0 to 507 bytes of data
    4. If the data was properly received by the destination node, the destination node sends another ACK. If the transmission was unsuccessful, the destination node does nothing, causing the source node to timeout. The source node will infer that transmission failed and will retry after it receives the token on the next token pass
    5. The token is passed to the next node
- If the desired message exceeds 507 bytes, the message is sent as a series of packets – one packet every token pass. This is called a fragmented message. The packets are recombined at the destination node to form the entire message

Broadcast Messages



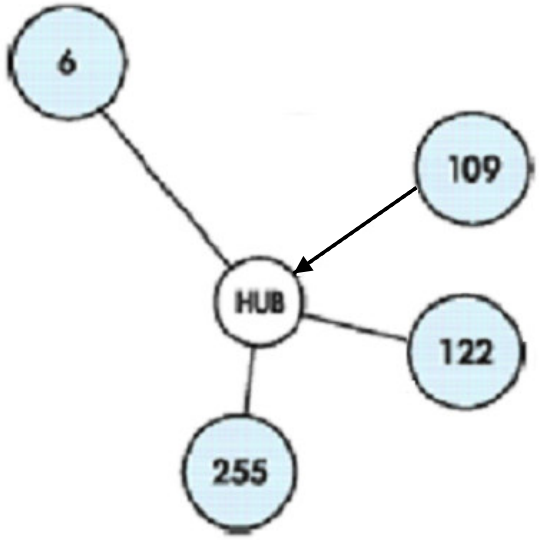
•ARCnet supports a broadcast message, which is an unacknowledged message to all nodes.

•Nodes that have been enabled to received broadcast messages will receive a message that specifies node 0 as the destination address.

•Node 0 does not exist on the network and is reserved for broadcast function

•No ACKs or NAKs are sent during a broadcast message making broadcast messaging fast

Automatic Reconfigurations



Control Network: ARCnet

Page 14

•ARCnet is able to reconfigure the network automatically if a node is either added to or deleted from the network. This reconfiguration process is automatic and quick without any software intervention.

•If a node joins the network, it does not automatically participate in the token-passing sequence. Once a node notices that it is never granted the token, it will jam the network with a reconfiguration burst that destroys the token-passing sequence. Once the token is lost, all nodes will cease transmitting and begin a timeout sequence based upon their own node address. The node with the highest address will timeout first and begin a token pass sequence to the node with the next highest address. If that node does not respond, it is assumed not to exist. The destination node address is incremented and the token resent. This process is repeated until a node responds. At that time, the token is released to the responding node and the address of the responding node is noted as the logical neighbor of the originating node. The process is repeated by all nodes until each node learns its logical neighbor. At that time the token passes from neighbor to neighbor without wasting time on absent addresses.

•RECON – Reconfiguration Burst <RSU><RSU>…<RSU> 765 RSUs

•If a node is unplugged from the network the reconfiguration sequence is slightly different. When a node releases the token to its logical neighbor, it continues to monitor network activity to ensure that the logical neighbor responded with either a token pass or a start of a transmission sequence. If no activity was sensed, the node that passed the token infers that its logical neighbor has left the network and immediately begins a search for a new logical neighbor by incrementing the node address of its logical neighbor and initiating a token pass. Network activity is again monitored and the incrementing process and resending of the token continues until a new logical neighbor is found. Once found, the network returns to the normal logical ring routine of passing tokens to logical neighbors.