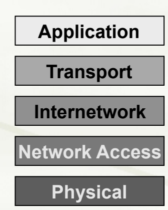
Extending the LAN

Info 341 Networking and Distributed Applications

Context

- Building up the network
  - Media
  - NIC
- How to hook things together



Internet Reference Model

Packet Collisions

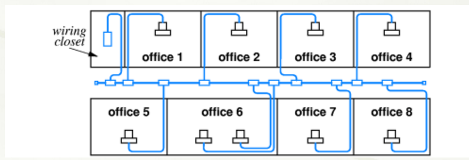
- What is a packet collision?
  - What happens when packets collide?
  - How does a machine respond?

Overriding Concept

- The "Segment"
  - A segment is a contiguous unit of a medium in which a packet collision might occur.
  - A single piece of cable that forms a bus

Segments

- How many segments?



Segments

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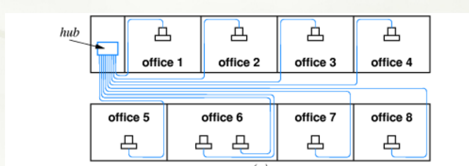

Segments

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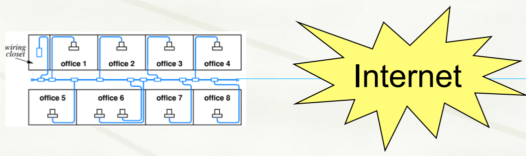

Maximum Segment Length

- For a given medium segment has a max length
  - Why?

Media Type	Name	Length
Thicknet (coax)	10 base 5	500m
Thinnet (coax)	10 base 2	200m
UTP	100 base T	100m
Fiber	1000 base FX	1.5km

Maximum Segment Length

- For a given medium segment has a max length
  - Why?
  - Signal attenuation
  - Distance a packet can travel in a given time

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LANs have limited Size

- The size of a LAN is limited by the type of the medium.
  - What's the largest LAN we could build?

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  - What's the largest LAN we could build?
    - What's the largest segment length?

LANs have limited Size

- The size of a LAN is limited by the type of the medium.
  - What's the largest LAN we could build?
    - What's the largest segment length?
  - What if we could hook two or more segments together?

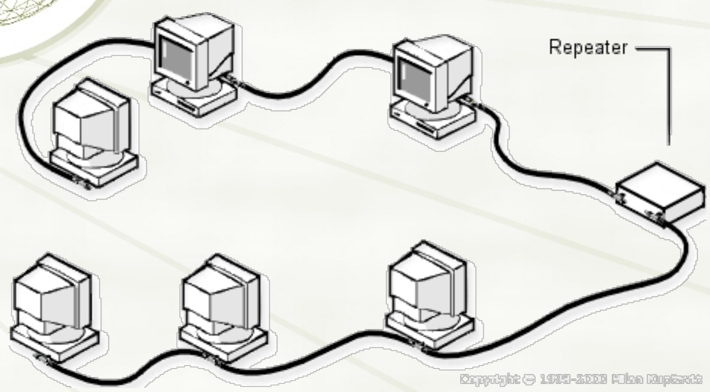
Connecting Segments

- Repeaters
- Bridges
- Hubs
- Switches

Repeaters

- Do exactly what their name implies
- Regenerate the signal so that it can travel a longer distance
  - For example you could extend the maximum length of a 10Base5 thicknet network from 500 meters to 1000 meters by installing a repeater at the end of one segment
- Thick Ethernet can have a maximum of 5 segments, 2500 meters total cable length

Repeater example



Bridge

- Regenerate the signal so that it can travel a longer distance
- A bridge keeps track of which devices are on different segments
- A bridge only retransmits signals when the sender and receiver are on different segments

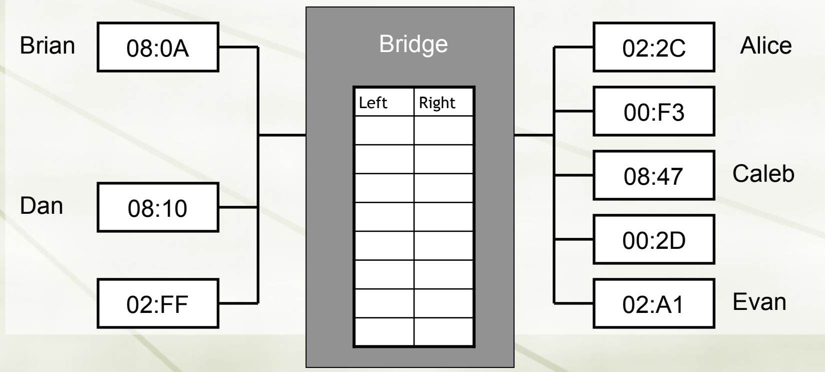
Bridge

- Bridges maintain a "bridge table" that keeps track of what addresses are on each side of the bridge
- Bridges help control congestion and can improve performance on a network
  - Why?

How Bridges Learn

- Bridges learn by watching the traffic that is on the network
- Bridges start by acting like a repeater, sending out all traffic
- Consider an example …

Building A Bridge Table



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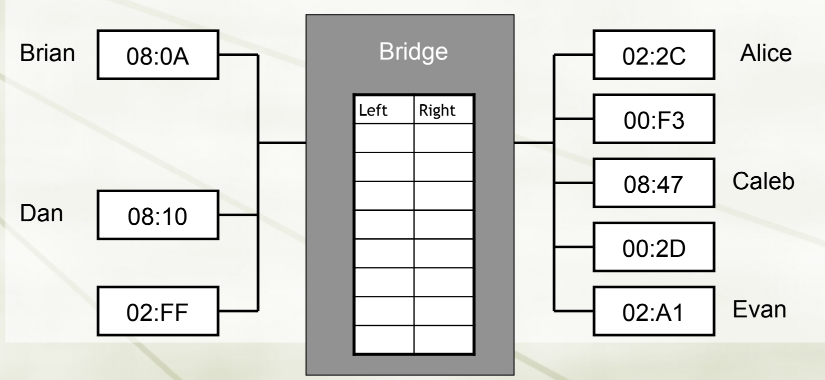

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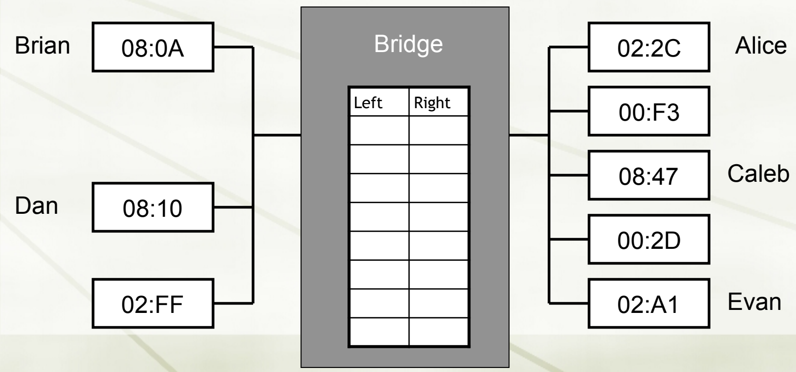

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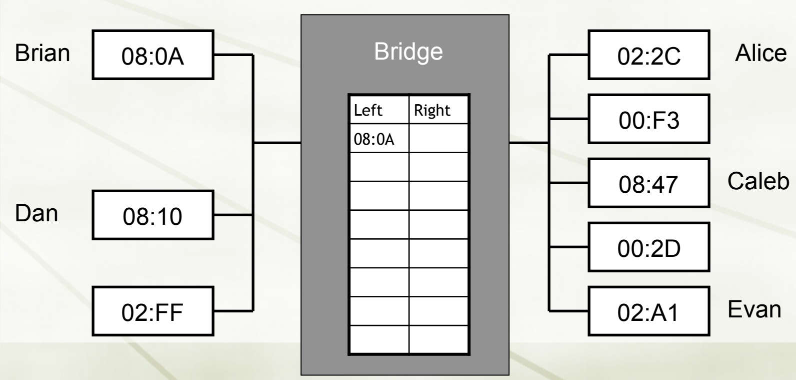

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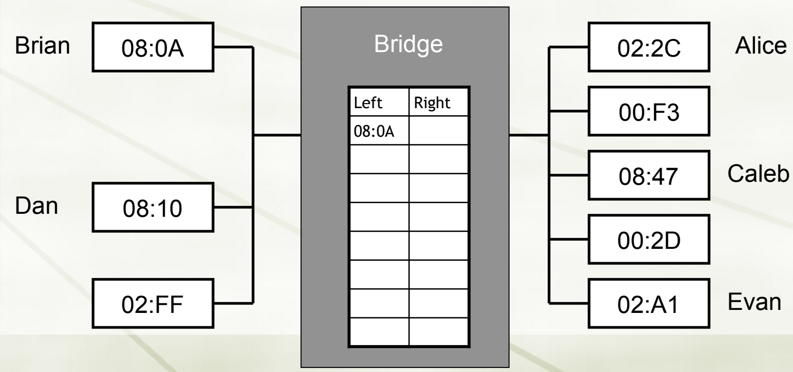

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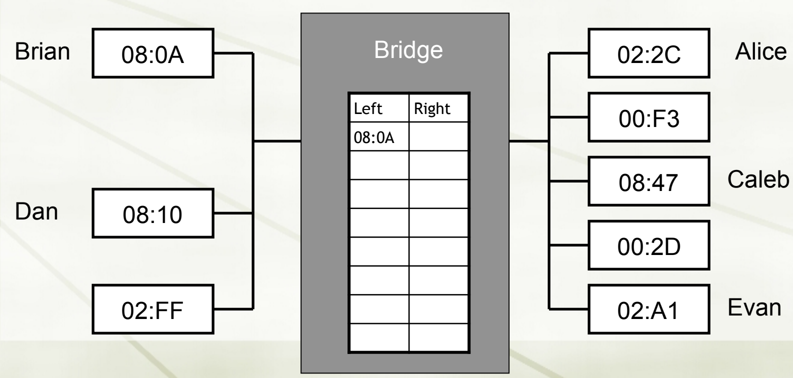

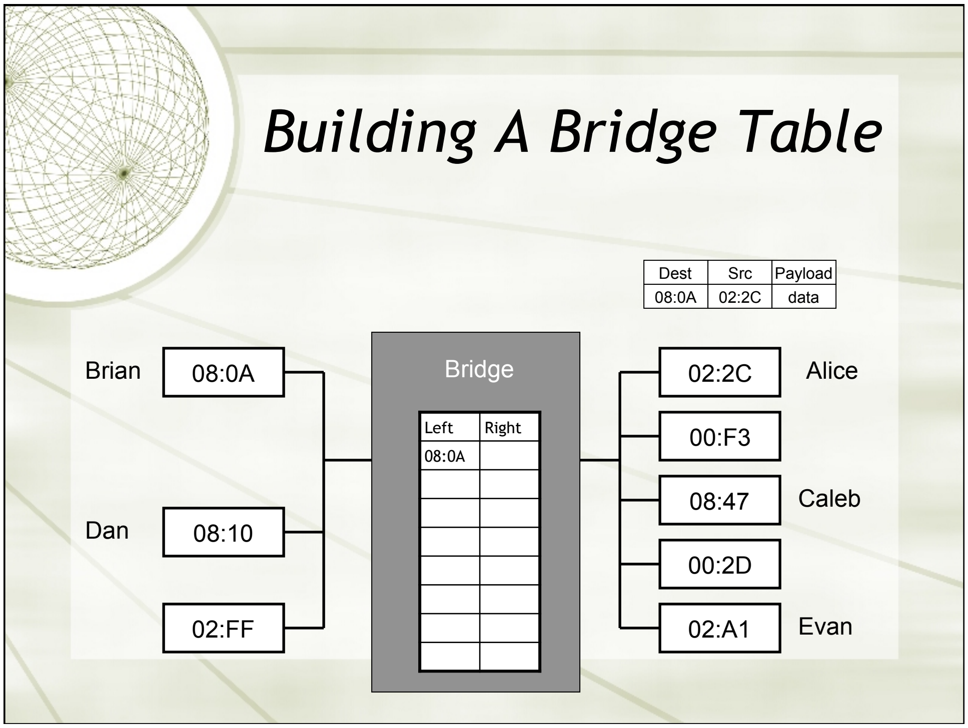
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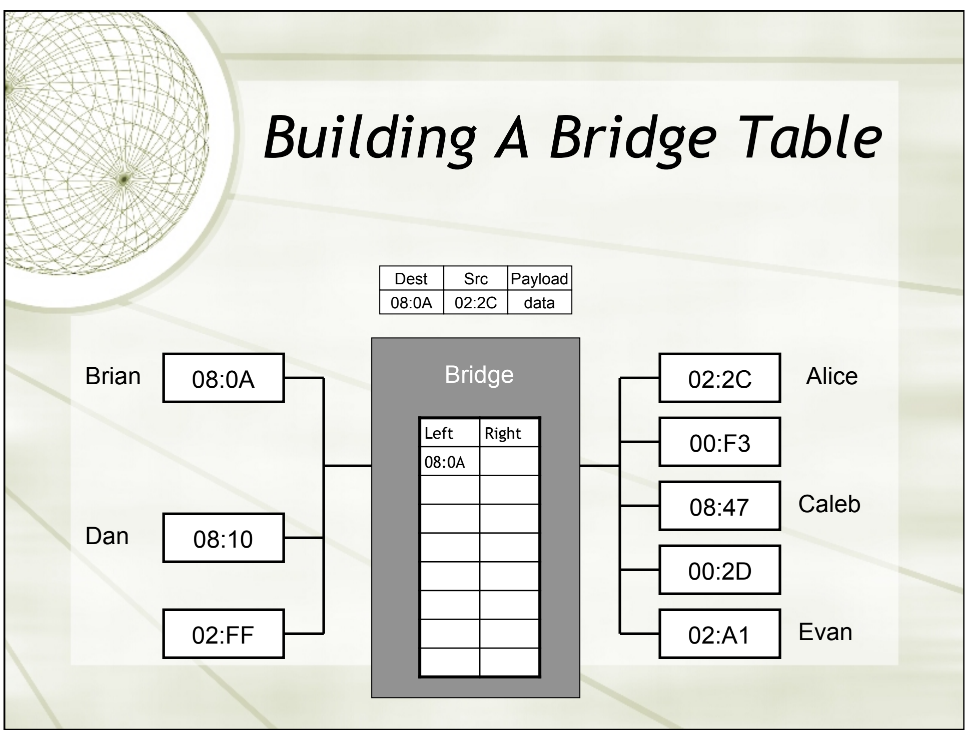
Dest
Src
Payload
08:0A
02:2C
data
Brian
08:0A
Dan
08:10
02:FF
Bridge
Left
Right
08:0A
02:2C
Alice
00:F3
08:47
Caleb
00:2D
02:A1
Evan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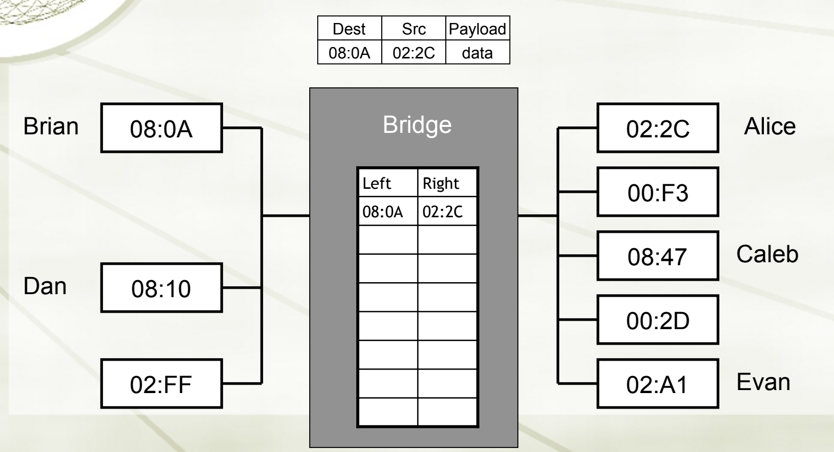

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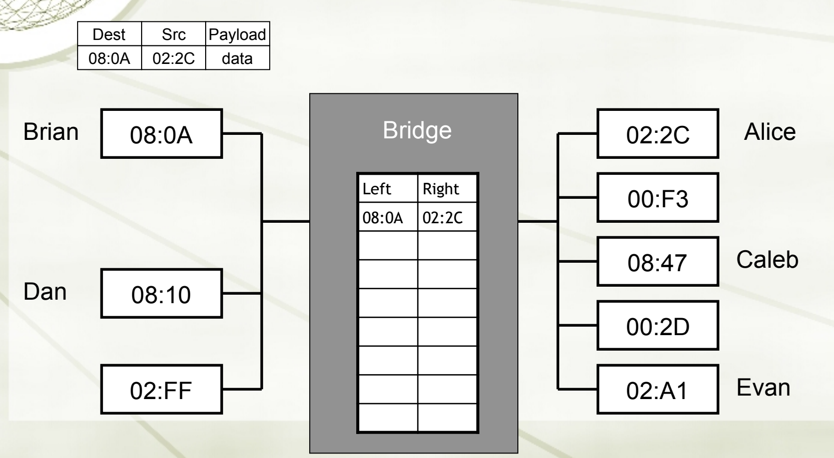

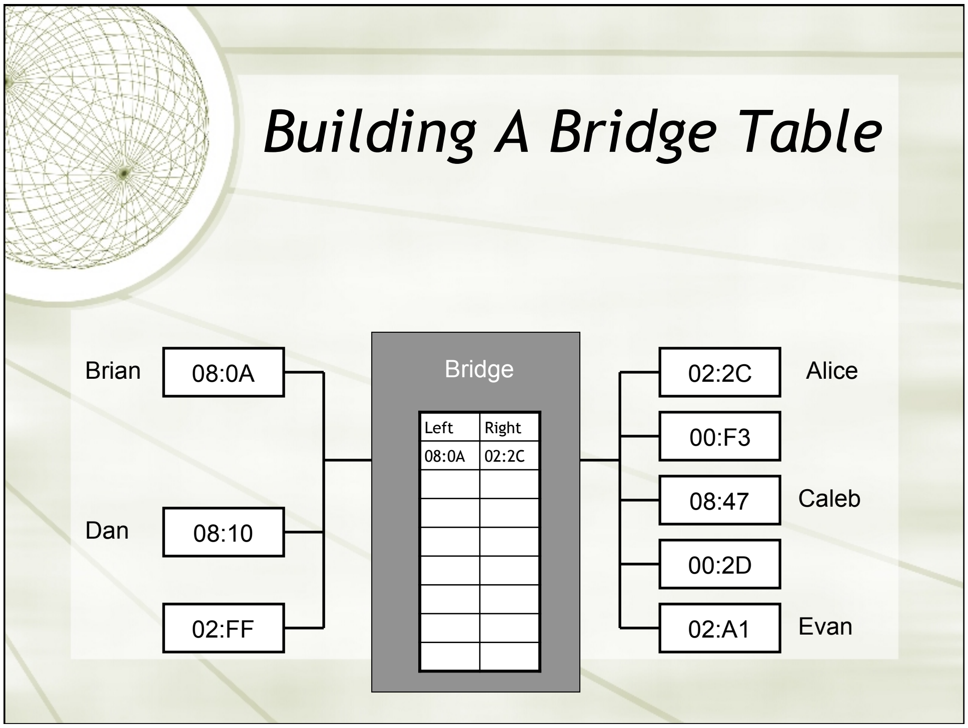
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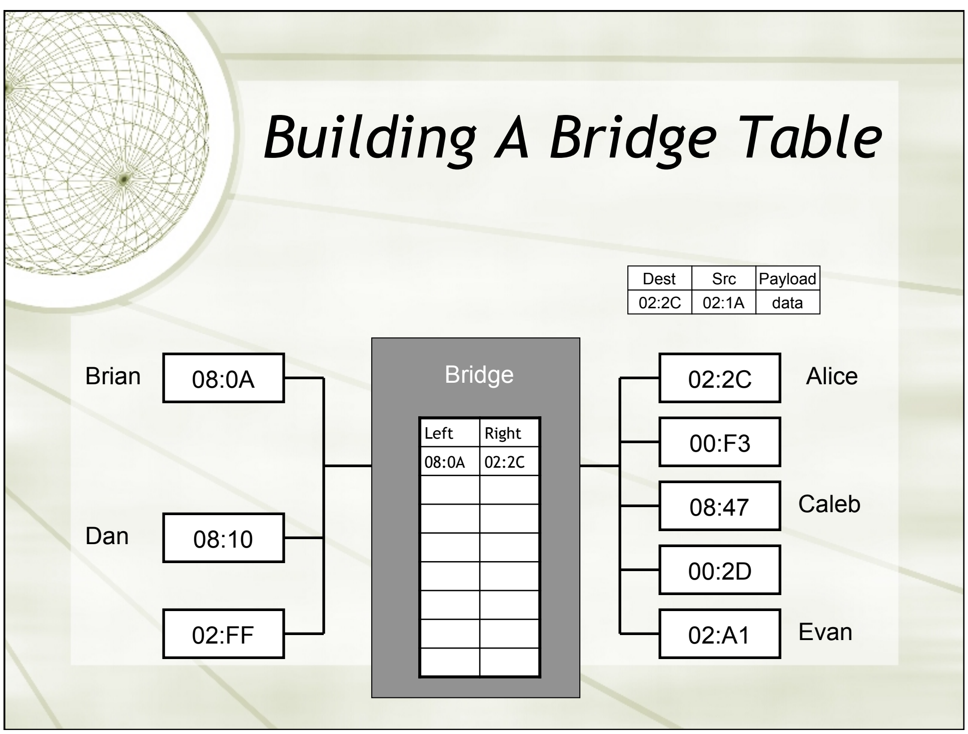
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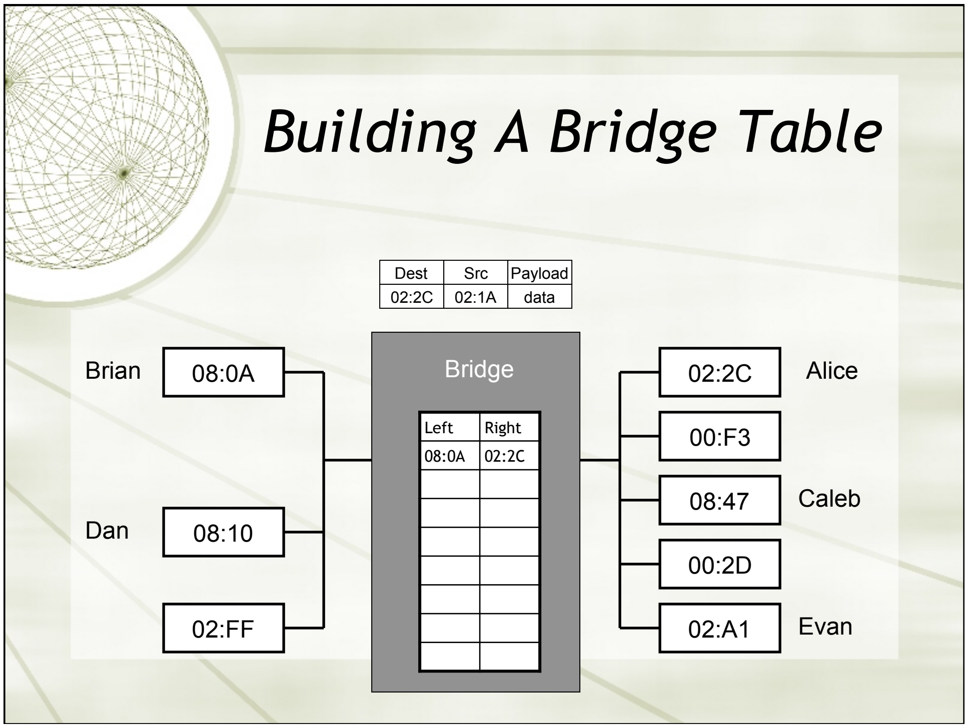
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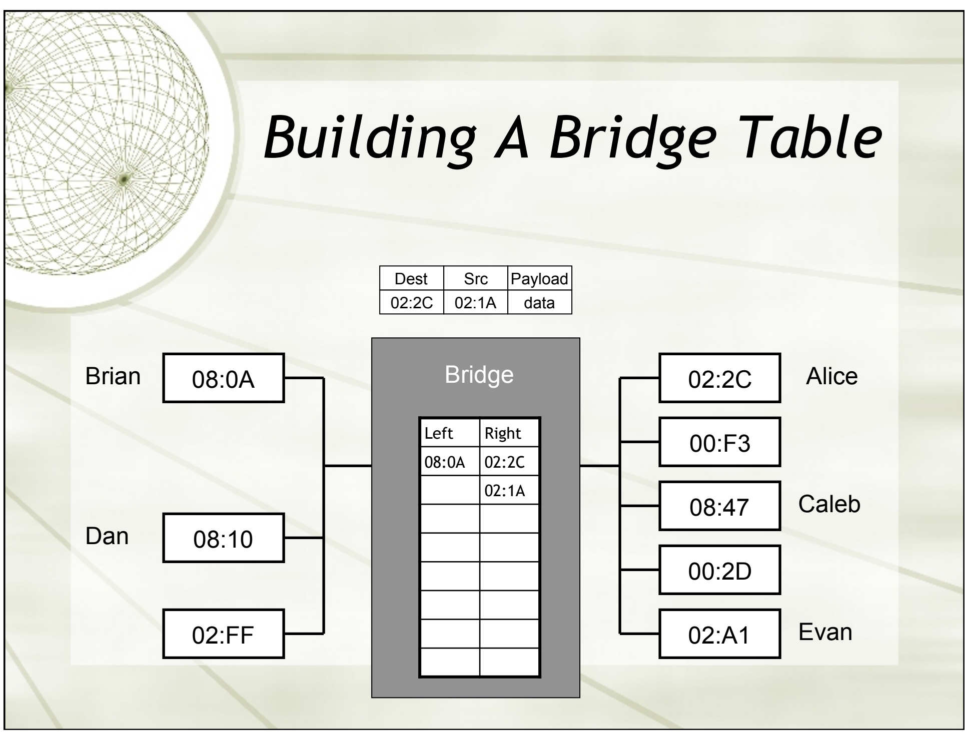
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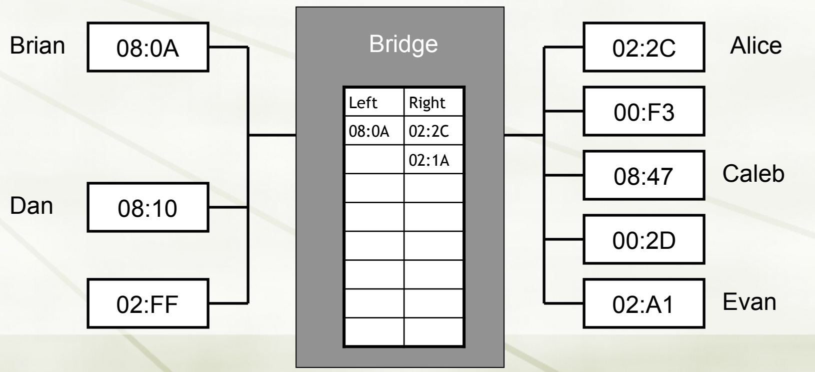

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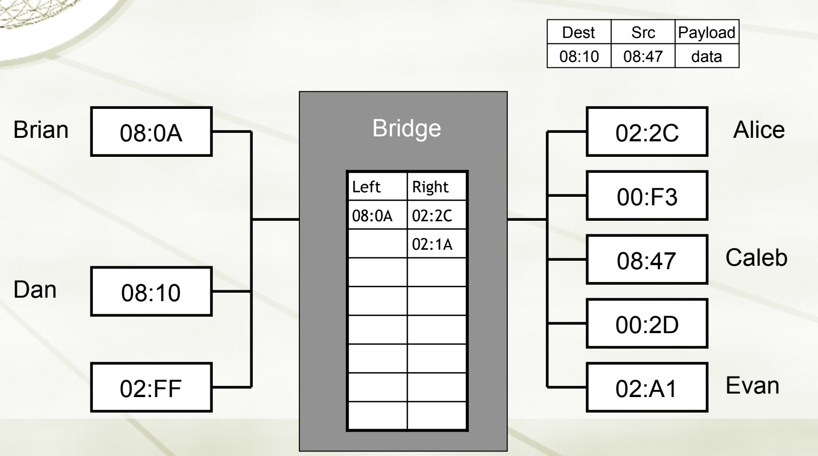

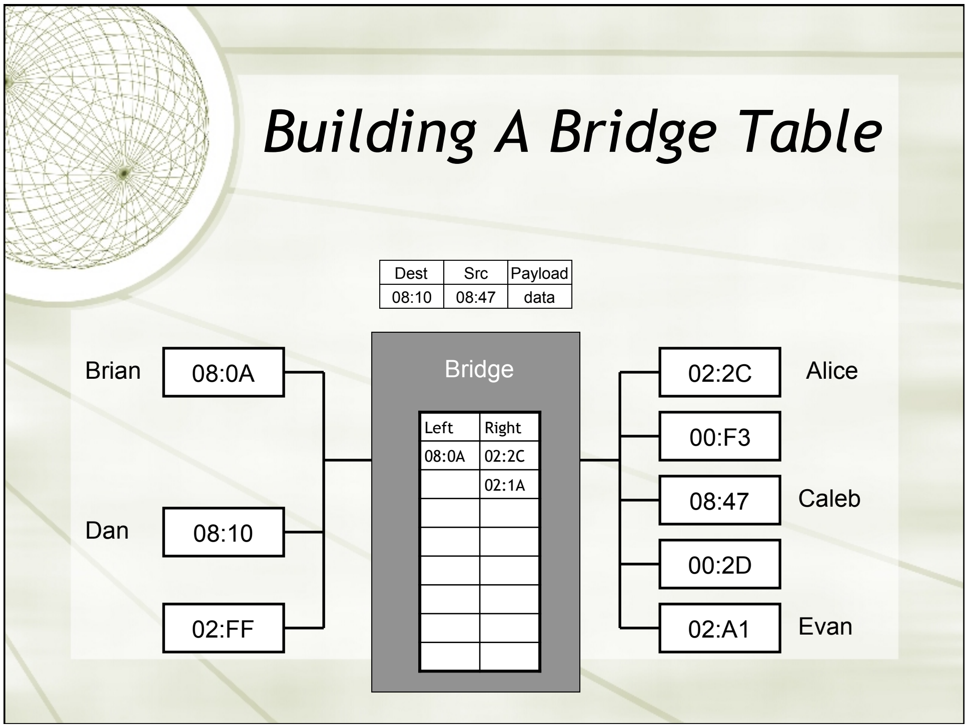
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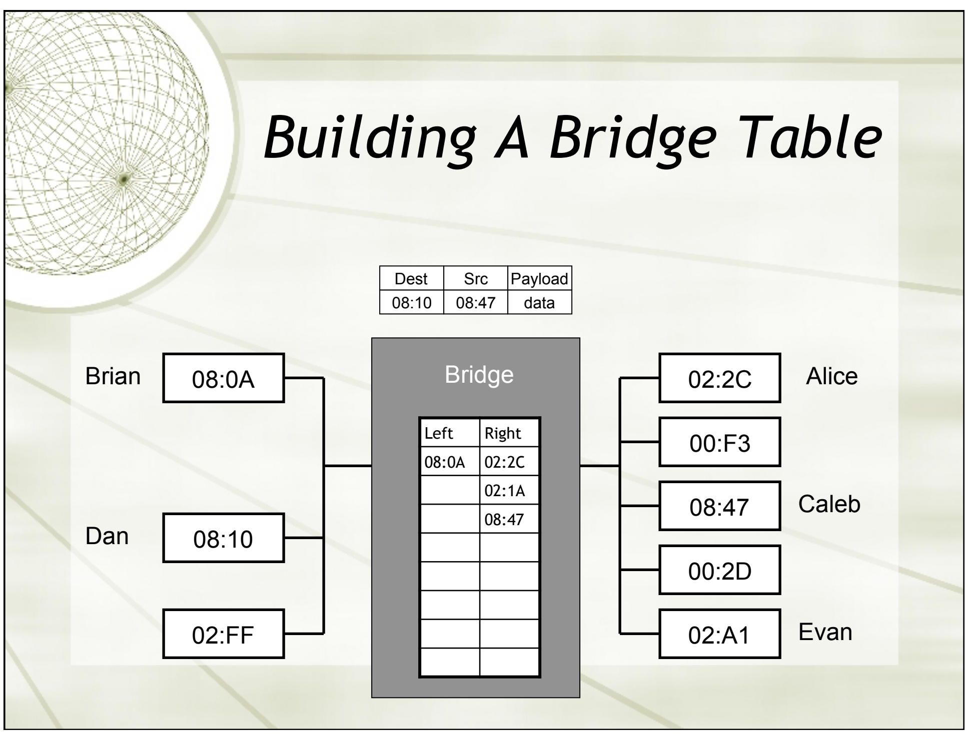
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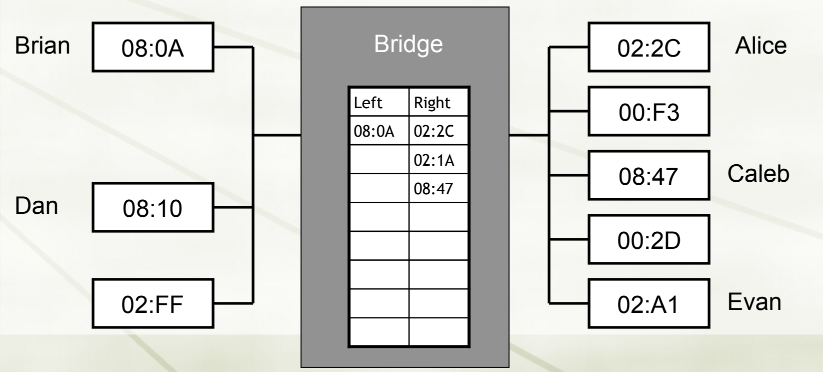

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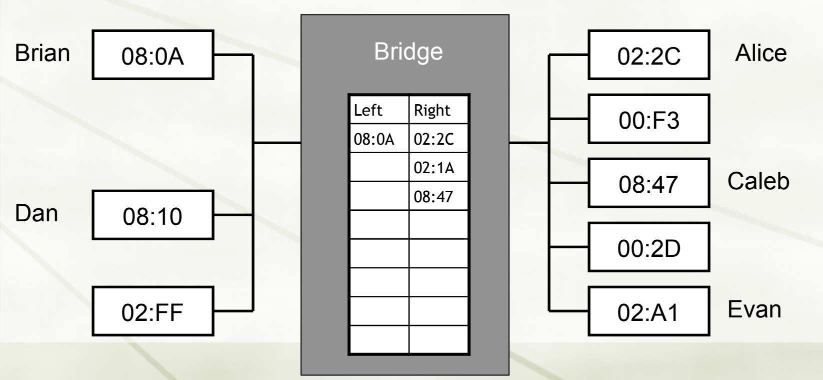


Congestion

- When a segment has lots of traffic (and lots of collisions) we say it is “congested”
- Now that you’ve seen an example, how does a bridge help control congestion?

Hubs

- Essentially a “multi-port repeater”
  - Propagates all the data on one cable to all the others connected there
- Comes in a variety of shapes and sizes with a varying number of ports.
- One port is often an “uplink” or “cross-over” port for connecting a series of hubs

Switches

- Switches physically resemble hubs
- Switches do NOT act like hubs
  - Switches act like bridges
- Layer 2 Switch
  - Learn MAC Addresses for each port (socket)
- Congestion is reduced
- Network performance improved

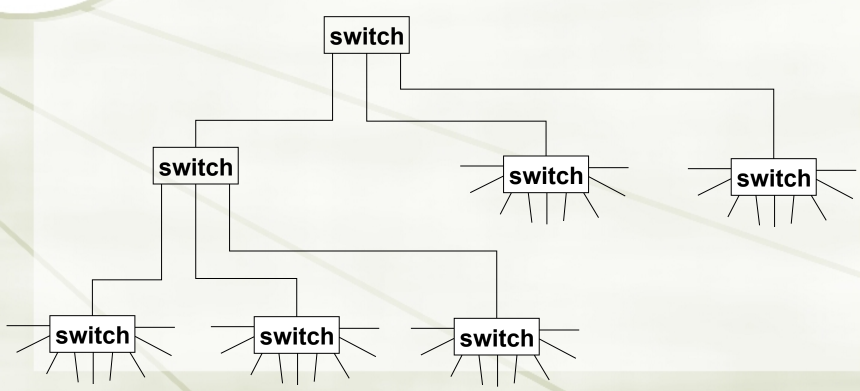
WANs and Routing

Context

- Connecting large numbers of machines
  - WANs span large distance
  - Bridging, repeating
  - Traffic control, congestion control
- Basic problem, how to make sure packets are delivered?

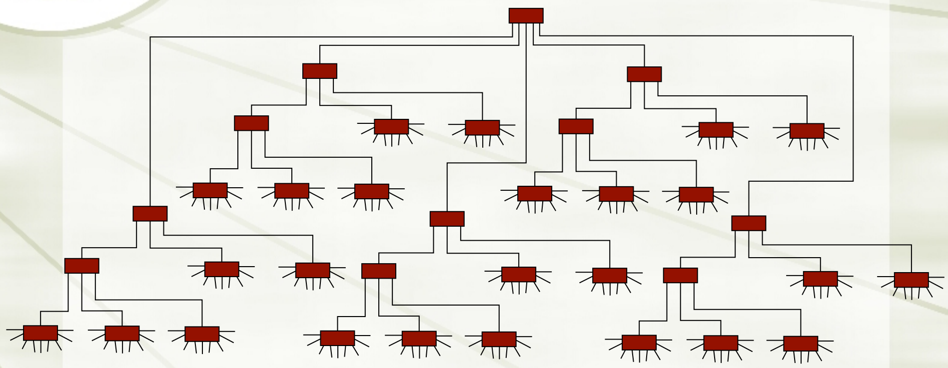
How do we hook up a bunch of machines?

- Maybe we could just use switches?



What if it got really big?

- What are the limits of this design?

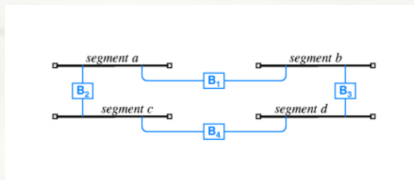


Problems with huge 'switched' networks

- Physically this looks to be hierarchical, but it is not
- Logically, the fully switched design is a 'flat' addressing space
- Every switch needs to know exactly what addresses exist on each port.
  - Limitation is memory - the tables get too big

Potential Problems with Cycles

- As you add bridges (switches) you might accidentally create a cycle



- Why is this a problem?

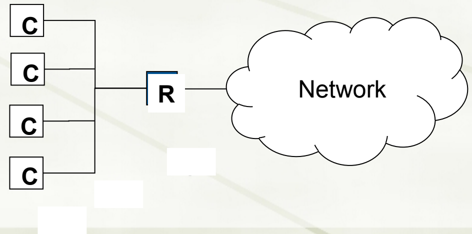
Potential Problems with Cycles

- Switches must pass all broadcast packets
  - Switches can't tell which broadcast packets they have seen and which are new
- May cause a broadcast storm that completely saturates the network
  - Some switches support the "spanning tree algorithm" to detect a cycle and cut it

Routers

Routers are special equipment helps traffic control

- Translate traffic between different types of network hardware (the whole world is not Ethernet)
- Routers often store and forward packets
  - memory in the router allows the router to store the packet, inspect/analyze the packet and then forward it to the destination



Routers

- Minimally routers have two NICs (which are usually called "interfaces") installed
- Each "interface" connects to a different network or LAN
- Routers can connect different types of networks
  - A router might have an Ethernet interface, a Token Ring interface, and a Fiber interface all in the same router
- Routers examine packets
  - They determine what packets should stay local to a particular network segment, and which need to be sent outside
  - Routers may have to re-package data into different frame types,
    - Token Ring frames can be up to 4500 bytes, Ethernet frames 1500 bytes
    - a router must put the correct envelopes around the data so it can be moved between different network types
  - Broadcasts DO NOT pass through routers

Routers and large networks

- While it is possible to build large networks using just switches, traditionally routers are used instead due to their ability to better control traffic and their ability to interconnect different network types
  - Routers however are much more expensive
  - Routers have to understand the higher level protocols, they don't just use MAC addresses so they must have fast CPUs.
  - Even the fastest router may not be as fast as a LAN switch since the switches job is much simpler, so a router based network could potentially be slower than a switched based network

Distinction

- Switched LAN vs Packet Switched Network
  - Previously, we talked about LAN switches and how they can help with congestion
    - LAN switches, Level 2 devices
  - Now, we're talking about packet switching - in general, routers perform packet switching
    - Routers, Level 3 devices
  - The term 'switched' means different things in different contexts

The Role of Routers

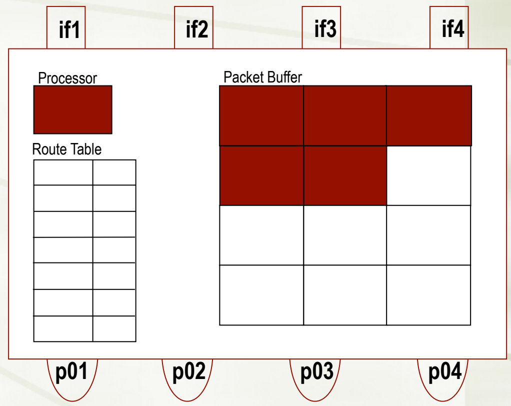
- The role of routers in a network
  - Traffic cop
  - Connect different types of networks
- How is this done?
  - First, a simple packet switching network…

A Small Abstract Network (SANet)

- SANet is not a real network, just a small example to facilitate some networking concepts
- SANet is composed of computers and routers
- SANet has packet structure and numerous possible interconnection topologies

SANet Router

- Router has
  - Processor
  - Route table
  - Packet buffer
  - "Interfaces"
    - Connect to the external network (WAN)
  - "Ports"
    - Connect to the internal network (LAN)



SANet Packets

- SANet has a frame structure composed of
  - Destination address
  - Source address
  - Payload
  - Checksum

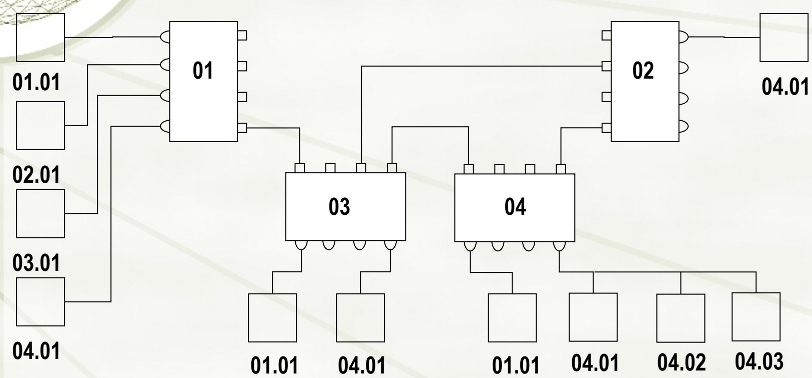
Address Structure

Router (1 octet)	Machine (1 octet (port) + 1 octet (machine))
01	00.02

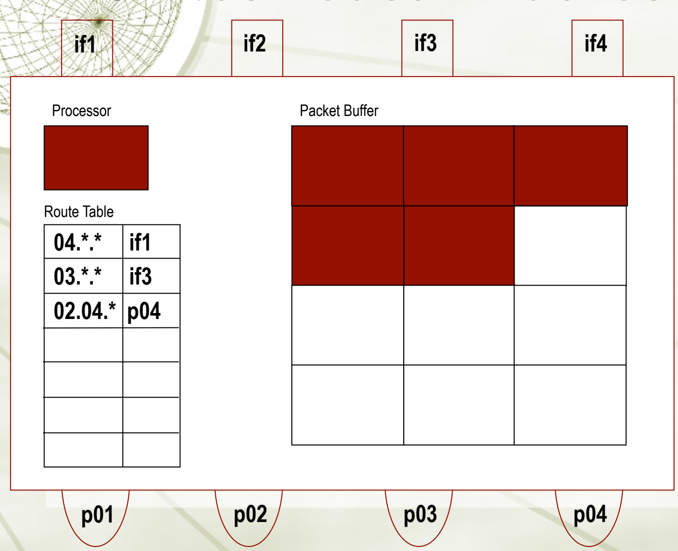
Packet Structure

Dest	Source	Payload (16 octets)	Checksum
02.04.01	01.02.01	00:00:00:00:00:00:00:00:00:00:00:00:00:00:00:00	00:00

SANet Architecture



SANet Router/Packet Switch



Switch 02

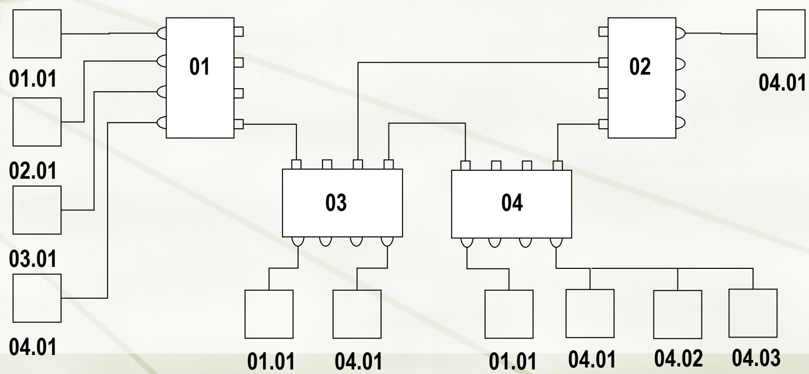
Route table keeps track of other "networks" on the interfaces.

Route table keeps track of what machines are on each port

Finding a path

02.04.01	01.01.01	ff:05:00:0a:00:00:00:0c:00:f5:00:ec:f3:00:27:13	1b:11

04.04.03	01.03.01	ac:00:0f:13:00:10:01:ee:10:00:00:65:aa:67:00:00	77:de



Routing Packets (SANet)

- SANet addressing is an example of hierarchical addressing
  - The address tells you something about the structure of the network
- Next-Hop
  - Examine the first part of the address
  - Table lookup determines where the packet is sent
- But how is a route determined/found?
  - Graph Theory

Routing Packets

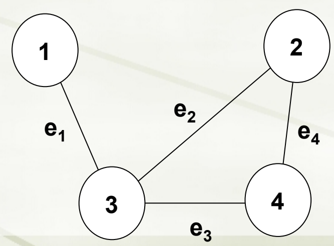
- Common Approaches
  - Static routing – fixes routes at start up – sometimes set by hand
  - Dynamic routing – programmatically build the route table
    - Often rely on graph theoretic approaches
    - Link State Routing (LSR)
    - Distance-Vector Routing (DVR)

Networks as Graph Theory

- Networks are a concrete representation of mathematical graph theory
- In graph theory a graph is:
    - nodes N= $\{n_1,n_2,n_3,n_4, \ldots n_n\}$
    - edges E = $\{e_1, e_2, e_3, e_4, \ldots e_n\}$
    - a function determining edge incidence

Graphs

- A graph of the SANet architecture
  - nodes N = {1,2,3,4}
  - edges E = {e_1, e_2, e_3, e_4}
  - e_1 = (1,3)
  - e_2 = (2,3)
  - e_3 = (3,4)
  - e_4 = (2,4)



Weighted Graphs

- A weighted graph is one where the edges have some weight or value associated with them
- Networks have various edge weights
  - Transmission speed (distance vector)
  - Transmission latency (distance vector)
  - Link live (link state/status)

Network Graph Algorithms

- Given a weighted graph
- Minimum Spanning Tree (MST)
  - Eliminate cycles in a graph
  - Used in intelligent switches and routers
  - Related, Distributed Spanning Tree (DST)
- Shortest path
  - Used in routers to determine the ‘shortest’ route for delivering a packet